PROGRESSIVE TECHNICAL SERIES

ENGINEERING DRAWING

BOOK I

JONES & LONGHURST

THE CLARKE & STUART COMPANY LIMITED

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ENGINEERING DRAWING AND SCIENCE

BOOK 1.

by

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AUTHORS' PREFACE

This progressive series of lessons is intended for those students who have already had a course in "Practical Plane and Solid Geometry" and who intend to take up some branch of Engineering. The chart on page viii. shows that Engineering Drawing is a pre-requisite to the special study requirements of each particular branch of Engineering. These lessons are made up from the fundamentals of all groups and are treated in an elementary manner.

This course has been worked out carefully in practice and each lesson should be presented to the student, if at all possible, with actual samples mounted on boards as in the lesson on "Keys and Shafts" illustrated on page ix. The "Analysis of Engineering Drawing Method" presents the manner in which the course should be taken. The student should be given the opportunity of learning through practical contact with real jobs. This will stimulate his respect and give him the urge to build up his own convictions which he will then record in the form of a drawing or sketch.

Engineering Drawing should not be taken as a copying or memorizing device with values based upon the "pretty picture" standard. Its value should be tested by sound practice to ascertain that it presents information and direction to workmen for the production and use of Engineering parts and devices.

Note. Complete sets of photographs of mounted boards (20 to set) may be obtained from the Publishers, The Clarke & Stuart Co. Ltd., Vancouver, B. C.

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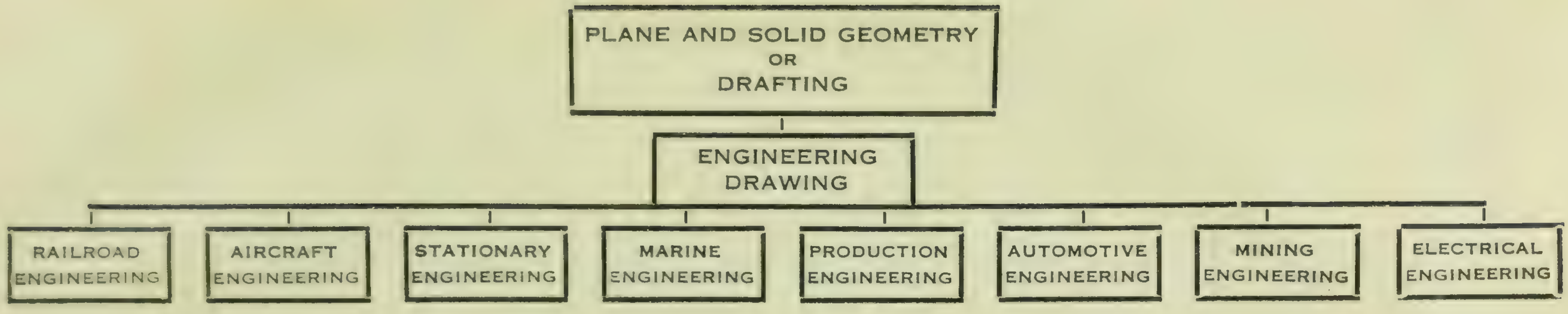


ANALYSIS OF ENGINEERING DRAWING METHOD

1. Principles of Plane and Solid Geometry should be studied in conjunction with their practical application to Engineering Drawing.
2. A student should realize that drawing is a means of representing solid objects on paper, therefore the actual object, or a model of it, should be available for examination by the student.
3. Freehand dimensioned sketches should be made direct with a pencil and paper from the actual objects. Drawings may be made with objects available in the early stages, but later drawings should be made from sketches only so that the student must take full responsibility to get all information necessary when preparing his sketches.
4. A completed drawing must be sufficient in itself to enable a workman to produce without further information the piece it represents.
5. The student's ability to read drawings may be tested by requiring the production of further views and sections from a given drawing or the production of a drawing from an idea.
6. Practice may also be given in the assembling of different pieces in their proper positions, the making of enlarged drawings of details, and the insertion of standard parts such as bolts, nuts, keys, etc., of which the student has learned the proportions.
7. All calculations necessary for the production of the drawings to be worked out in detail by the student and to be shown with the drawings.

ix.

ENGINEERING DRAWING
AND SCIENCE

USE OF DRAFTING EQUIPMENT

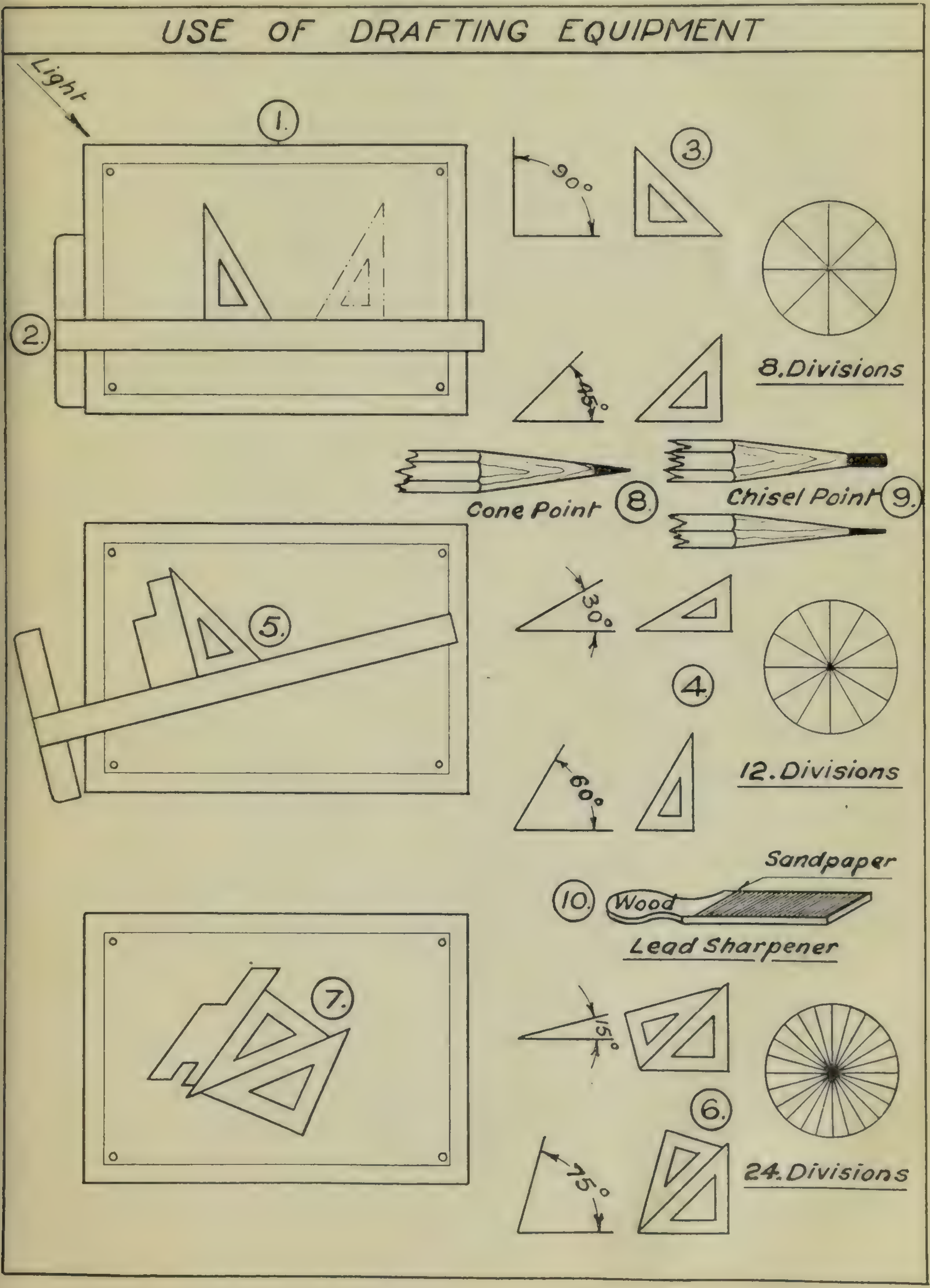
The equipment described in this lesson is that required for pencil drawings only. Equipment required for ink drawings will be described in a later lesson. It is not advisable to purchase a lot of expensive equipment at first, but rather to select good equipment as it is required and add to it as it is necessary for the work to be done. This lesson will deal with minimum requirements and suggestions for further additions will be mentioned as the need arises.

Drawing Board (Diagram 1). For the early lessons using a 9″x12″ piece of drawing paper, a board large enough to accommodate the paper will be sufficient. Later on 15″x22″ sheets will be used, so that a drawing board this size will accommodate the elementary and advanced course of work. The board should be made of well seasoned wood and strengthened by two battens to prevent warping. Allowance is sometimes made in fastening the battens for contraction and expansion due to atmospheric conditions. The drawing board edges are at right angles to each other so that the tee square can be used from any edge to produce lines at right angles.

The Tee Square (Diagram 2). Consists of two parts, the "stock" and the "blade," which are at right angles to each other. The Tee Square should be made from some hardwood; the best are provided with an ebony or celluloid edge to provide a smooth guide to the pencil or pen.

Set Squares (Diagrams 3 and 4). Two of these are required, one 30°, 60° and 90°, and one 45° and 90°. They are usually made of celluloid, and therefore are transparent, which is often a help in seeing lines covered by the set square. These triangles or set squares should be thick rather than thin, and the sizes as follows: 45°—8 inch, 60°—10 inch. Diagrams 1 and 5 show the set square used for obtaining lines at right angles to the tee square.

Angles Obtained by the Set Square. Angles shown 90°, 45°, 30°, 60°, 15°, 75°. These angles can also be used in dividing a circle of 360°. The 45° set square divides the circle into 8 equal divisions, diagram 3. The 60° and 30° set square into 12 equal divisions, diagram 4, and the 45° and 60° set squares used together into 24 divisions, diagram 6.


USE OF DRAFTING EQUIPMENT
Light
1.
2.
90°
3.
8.Divisions
45°
Cone Point
8.
Chisel Point
9.
5.
30°
4.
12.Divisions
60°
Sandpaper
10.
Wood
Lead Sharpener
7.
15°
6.
24.Divisions
75°

Drawing Parallel Lines with Set Squares. Diagram 5 shows the 60° set square used to draw parallel lines by moving it along the tee square. Diagram 7 shows the 60° set square used to draw parallel lines by moving it along the stationary edge of the 45° set square.

Pencils. Two types of pencils are used—diagram 8, the cone point, and diagram 9, the chisel point. After the wood has been removed from the point of the pencil with a pocket knife, the lead is sharpened on a lead sharpener, diagram 10. One pencil should be chisel pointed and should be hard and marked H or HH. The other pencil should be cone pointed and should be soft and marked HB. This pencil is used for sketching and freehand work generally, including arrow points and figures.

Drawing Paper. Cartridge paper is made in sheets of various sizes and is also sold in rolls. Hand-made paper is best, but it is expensive. For ordinary elementary work the student should obtain cartridge paper, the size required for his drawing. The following surfaces may be obtained.

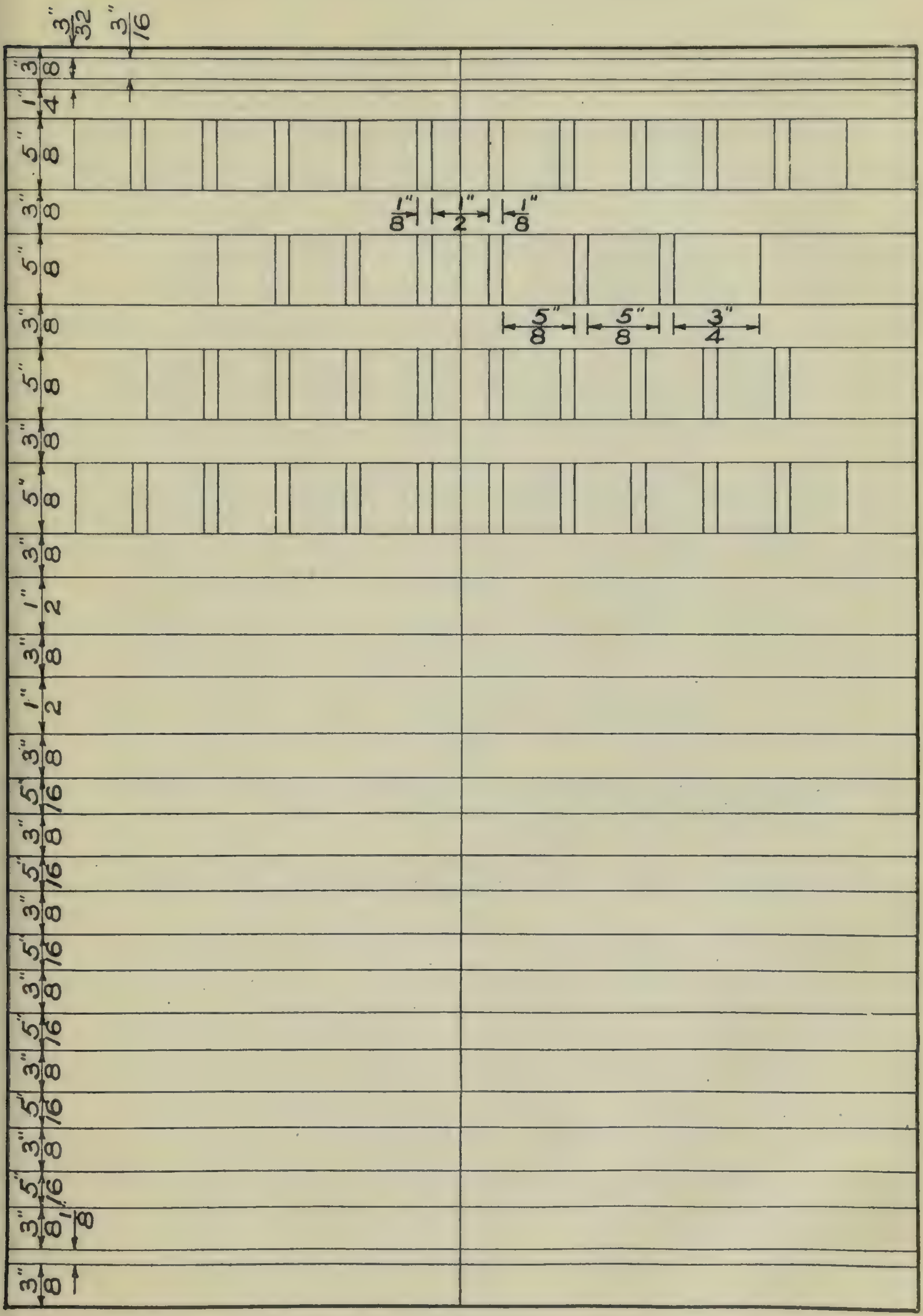
Hot-pressed. This paper has a smooth surface and is desirable for fine line drawings.

Not Hot-pressed. A fine grained surface for general work.

Rough or Cold-pressed. Used for sketching, but it is not suitable for machine drawing.

Instruments for Elementary Work. 1—5½″ compass (preferably with a pencil leg, a pen leg and extension bar). 1—5″ plain divider, 1 bow pencil compass, 8 thumb tacks, 1 pencil eraser, 1—12″ scale. See page 15.

Exercise: On a 9″x12″ piece of drawing paper, draw the guide lines as shown. This sheet will be used later for your lettering exercises. It will give you an opportunity to practise the use of the tee square and set square, and to measure the divisions as specified with a scale. (Full size.) Do not put in dimensions. Border size 8″x11″.


3"/32
3"/16
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PRINTING

Engineering Drawings may have their appearance spoiled by poor printing. It is necessary therefore for the student who is learning how to draw to place equal emphasis in learning how to print. Elaborate styles of printing are not necessary and have no place in Engineering Drawing. The mechanical characteristic of Engineering work calls for plain, clear styles of printing. It must be understood however that varied styles may be used in the different industries, and each individual will naturally develop characteristics of his own.

Some students feel they have no natural aptitude or ability to print. This is quite true to some extent, although the writer has trained many such students and has found that by following a few simple rules, clear readable printing can be produced by anyone who is ready to take a little time for practicing such simple rules.

Upper Case and Lower Case Letters. Upper case letters are shown on upper part of the adjacent lettering sheet. These capital letters, as they are sometimes called, are single line—Gothic in style and very simple in form. The lower case letters are small letters and are also single line Gothic in style.

The terms "upper" and "lower" case are borrowed from the printers because the capital type is placed in an upper case and the smaller letters in a lower case, when type is being set up.

Type of Printing for a Drawing. Some draftsmen use capital letters for drawing entirely, while others use both upper case letters and lower case letters. In the exercises given in this book capital letters are used for the titles of the drawing exercises and the lower case letters for all notations.

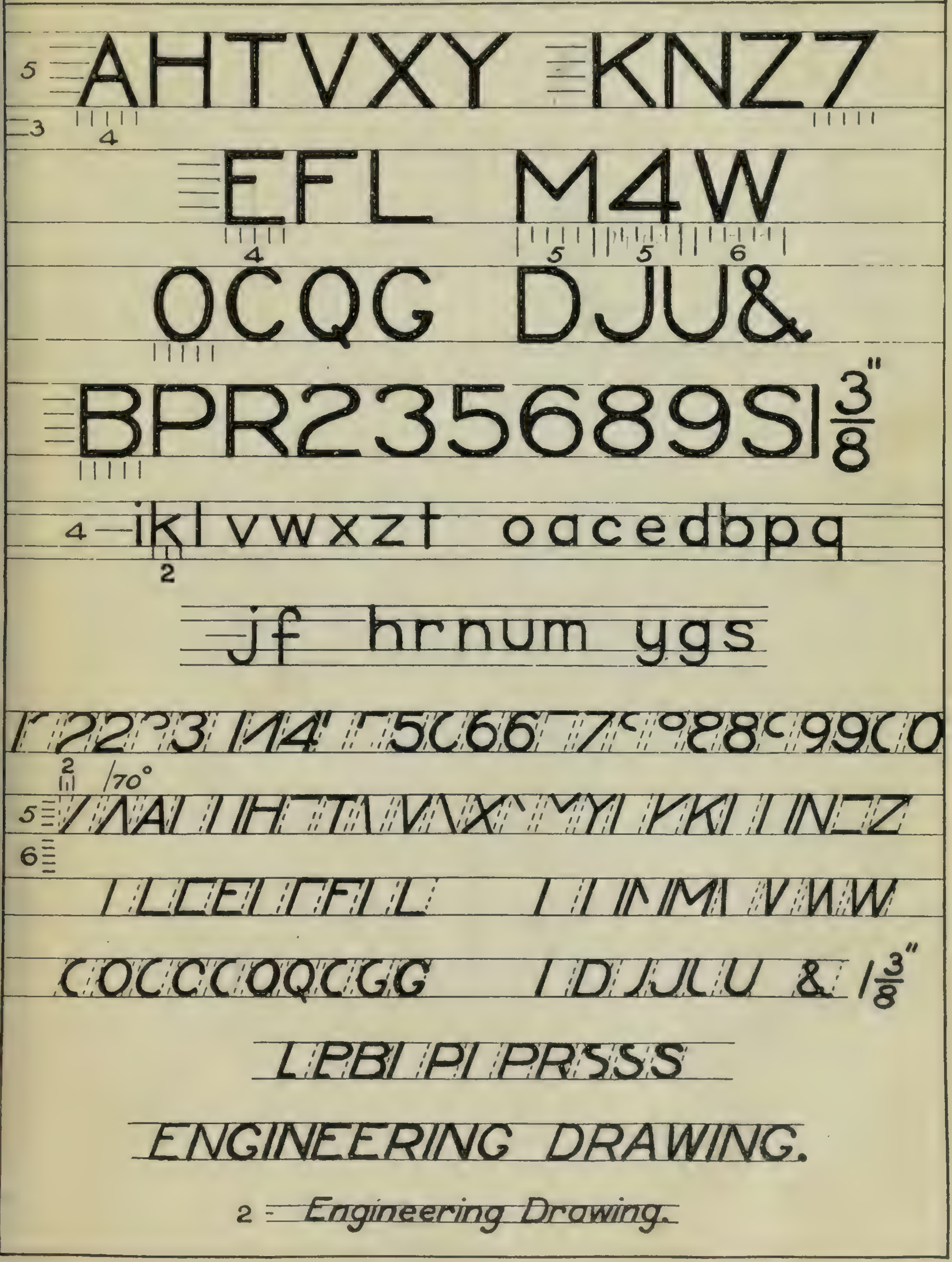
Vertical or Sloping Printing. Some engineers use the vertical style entirely, while others prefer the sloping style. The student will be advised to practise both and use the one that he can use best, or be ready to use the style he is told to use.

The vertical style is simpler to use for most students, but the sloping style gives a certain "liveliness" to a drawing.

The slope suggested here on the letter sheet is 5 units high and 2 units slope, which is approximately 70°. Some students find it a help to make a special 70° set square for lettering.

Geometric and Freehand Printing. In this lesson the student is advised to start printing with the aid of a ruler, tee square, and set square, as shown in the upper letter diagrams. When these capitals and figures have been well formed proceed with the freehand letters and make it your objective to print freehand with a neat uniform clear style, as most of the printing you will be called upon to do must be done quickly by the freehand method.

LETTERING EXERCISE.



Proportions of Letters and Figures. The first line on the letter sheet shows letters 5 units high and 4 units wide. The upper half of the lesson shows a ⅛″ unit, and lower half, with the exception of the last line a 1/16″ unit. The exceptions are the figures and letters (M) 5 units wide, (4) 5 units wide, and (W) 6 units wide.

The lower case letters are 2 units wide and 2 units high with the exception of k, l, t, d, b, p, q, j, h, y, g, which are 3 units high and the letter (f) 4 units high.

Strokes Used in Printing. This varies somewhat with the individual, but as a general rule the strokes are horizontal from left to right, or downward. The system of strokes is illustrated in the sloping style, the lower half of the page duplicating the letter and figure groups in the upper half of the page.

To Apply Printing to a Drawing. This must be designed before the printing is started. **For example, Engineering Drawing** is to be printed in the center of the page or sheet, balanced about a vertical center line. Count the letters and count one for the space between the words. This gives a count of 19 which would place one letter on the center line and 9 letters on each side. Draw the guide lines 5 units or 5/16″ high, and 4 units 4/16″ or ¼″ wide. Start from the centre line and work outward, leaving a space between each letter 1 unit or 1/16″ wide. Use a 70° set square and block out the letter spaces, then form the letters of the words. Apply the same method to the lower case example of Engineering Drawing on the bottom line, but do this example ⅛″ high direct (without the aid of sloping guide lines) to see if the slope, form and spacing of letters has been mastered.

To apply printing to a Tracing title. First print the letters required for the title between guide lines on a piece of paper. Find the centre of these letters with a rule. Place the printed paper beneath the tracing paper with centre lines coinciding and parallel with the border. Trace the printing.

Exercise: On the 9″x12″ piece of drawing paper (already prepared with guides from a previous lesson) duplicate the printed page as shown.

ABBREVIATIONS

Aluminum	AL.
Alternating Current	A.C.
Asbestos	Asb.
Babbitt	Bb.
Brass	Br.
Bronze	Brz.
Bushing	Bush.
Cast	C.
Cold Rolled Steel	C.R.S.
Copper	Cop.
Corrugated	Corr.
Countersink	Csk.
Counterbore	C'bore
Degrees	° or Deg.
Diameter	Dia.
Direct Current	D.C.
Drawing	Dwg.
Estimate	Est.
Example	Ex.
Feet	Ft.
Fibre	Fbr.
Figure	Fig.
Fillister	Fil.
Finish	F or Fin.
Finish All Over	F.A.O.
Forging	Frg.
Galvanized	Galv.
Gauge	Ga.
Class	Cl.
Hard	Hrd.
Head	Hd.
Headless	Hdlss.
Hexagon	Hex.
Inches	Ins.
Iron	I.
Key Seat	K.S.
Keyway	K.W.
Kilowatt	K.W.
Lead	Ld.
Machine	Mch.
Malleable	M.
Manganese	Mngs.
Maximum	Max
Mechanics	Mech.
Medium	Med.
Material	Mat.
Minimum	Min.
Number	No.
Octagon	Oct.
Ounce	Oz.
Patent	Pat.
Pattern	Patt.
Phosphor	Ph.
Point	Pt.
Porcelain	Prcln.
Pound	lb.
Radius	Rad. or R.
Round	Rd.
Rubber	Rub.
Safety Set Screw	S.S.Sc.
Screw	Sc.
Sketch	Sk.
Spring	Spg.
Square	Sq.
Steel	S.
Structural	Str.
Temperature	Temp.
Threads	Thds.
Tool	T.
Washer	Wshr.
Wire	Wr.
Wood	Wd.
Wrought	W.
Yard	Yd.
Yellow Pine	Y.P.

METHODS OF REPRESENTING AN OBJECT

The various methods of representing an object have been grouped on one sheet to give the student an opportunity to compare them. By this comparison the various features of each method will be simplified and each method should be better understood. The base of a Surface Gauge has been taken as the object throughout.

The Photograph. Shown in position (1), is used for industrial advertising to give prospective customers a realistic idea of what the object, machine or part looks like. Sometimes several photographs may be used showing how the object may appear from various view points.

Perspective Drawing (shown in diagram 2). This is the type of drawing used to represent an object as it actually looks to the human eye. All the lines representing parallel edges are drawn sloping towards each other to meet at a vanishing point. This type of drawing is very seldom used in engineering work, but is used considerably in architectural work.

Orthographic Drawing (shown in diagrams in group 3). These diagrams are drawn by **3rd angle projection.** Each view is the true shape of the object by actual measurement. The photograph and perspective views are not true shapes by actual measurement. Diagram A shows the top plan, B shows an end view of the end of the object nearest to the diagram B. Diagram C shows the front elevation and diagram D another end view of the end of the object nearest to it. Diagram E shows the bottom plan of the object.

Oblique Projection (shown in diagram 4). Shows one face of the object as the true shape by actual measurement. The two ends are drawn at a 30° angle and the measurements are made along these lines. Sometimes an angle of 45° is used.

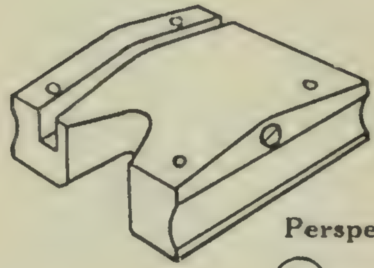
Isometric Projection (shown in diagram 5). None of the faces of the object have a true shape when drawn by this method. The sides and ends of the object are represented by lines drawn at a 30° angle. The measurements are made along these lines.

NOTE: No exercise is given with this lesson. It will be used frequently for reference.

METHODS OF REPRESENTING AN OBJECT

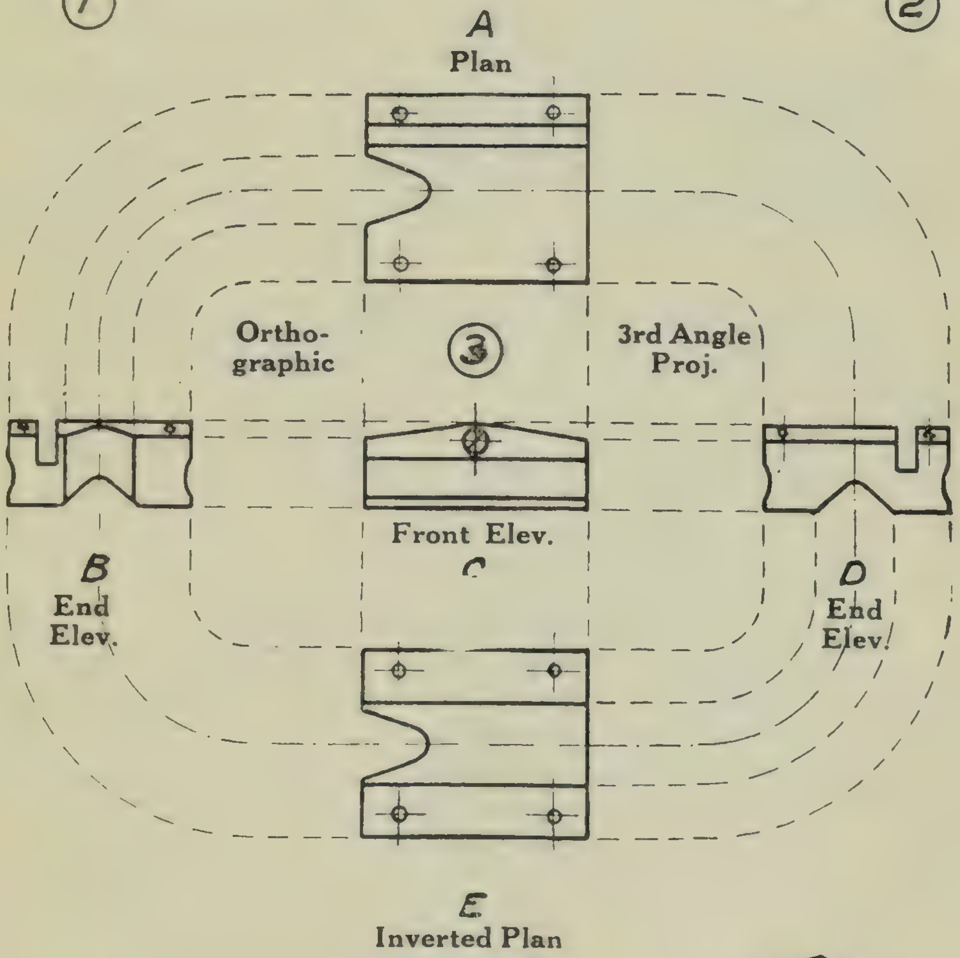
Photograph

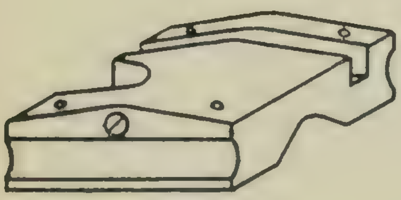
①



Perspective

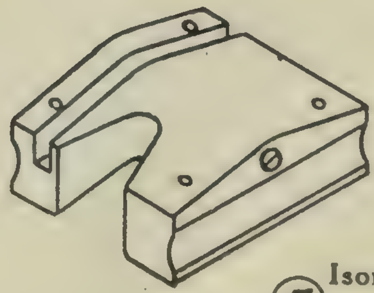
②





Oblique

④



Isometric

⑤

ROLLED SECTIONS OF IRON AND STEEL

The purpose of this lesson is two-fold.

1. To give you an opportunity of learning the shapes and properties of iron and steel which can be rolled into various forms.
2. To prepare you for freehand sketching, by duplicating the diagrams on the opposite page, with the assistance of your drawing equipment for the layout of the shapes. After rubbing out all construction lines, line in freehand with an H.B. pencil all lines except circles or parts of circles, which may be done with a compass. All circles are ¾″ diameter, and the squares, hexagons and octagons are obtained by drawing lines at a tangent to a ¾″ diameter circle. All other measurements may be obtained by using the ⅝″ to 1″ scale to find the dimensions from the printed diagrams, or estimate them approximately with your eye.

Tool Steel. The samples shown are of carbon tool steel and can be hardened and tempered. The carbon content of the steels vary according to the nature of the tool to be made from the bar or rod. In purchasing tool steel it is advisable to state the use you wish to make of it, so that the proper steel may be provided for that purpose.

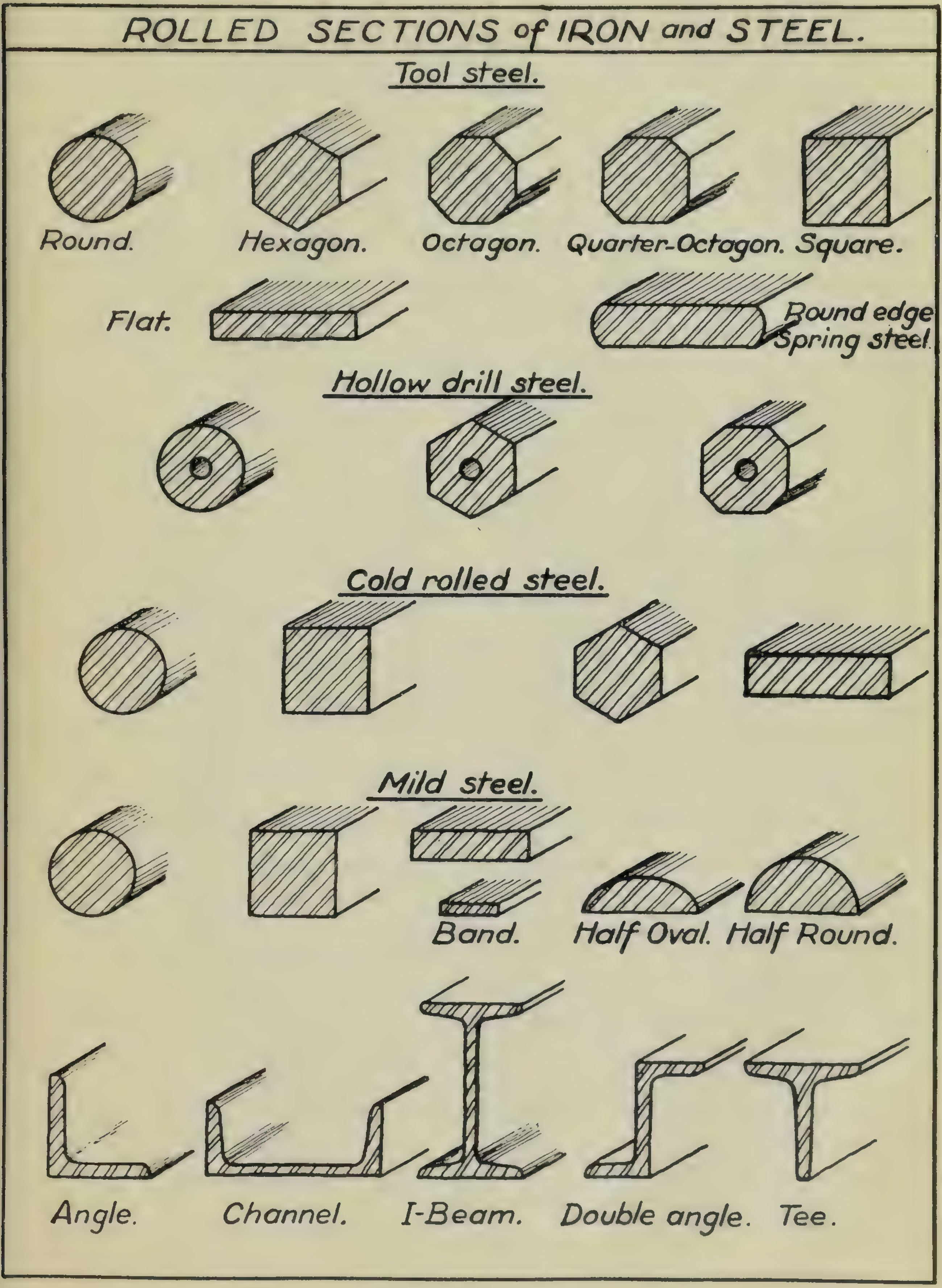
Special Alloy Tool Steels may be obtained, such as special chisel steels, which cost more than straight carbon steels, but are worth the difference in the increased life of the tools.

Hollow Drill Steel. This is a tool steel and is used in mining. The hole in the centre is made smooth and clean, to provide a free passage for air or water through the drill. The cutting points are "upset" and formed on the end of the drill for cutting into rock.

Cold Rolled Steel. This is a bright, finished stock, and is usually made of a carbon content too low to be hardened and tempered, but it can be case-hardened. The cold working of the metal gives it a hard outside layer with a tough core. It is accurate to size, and round stock is used for shafting. Square stock is used for keys, guides, etc., and hexagon stock for making bolts, etc., on automatic machines. The flat stock is used for keys, racks, guides, slides, etc., as it is straight and accurate.

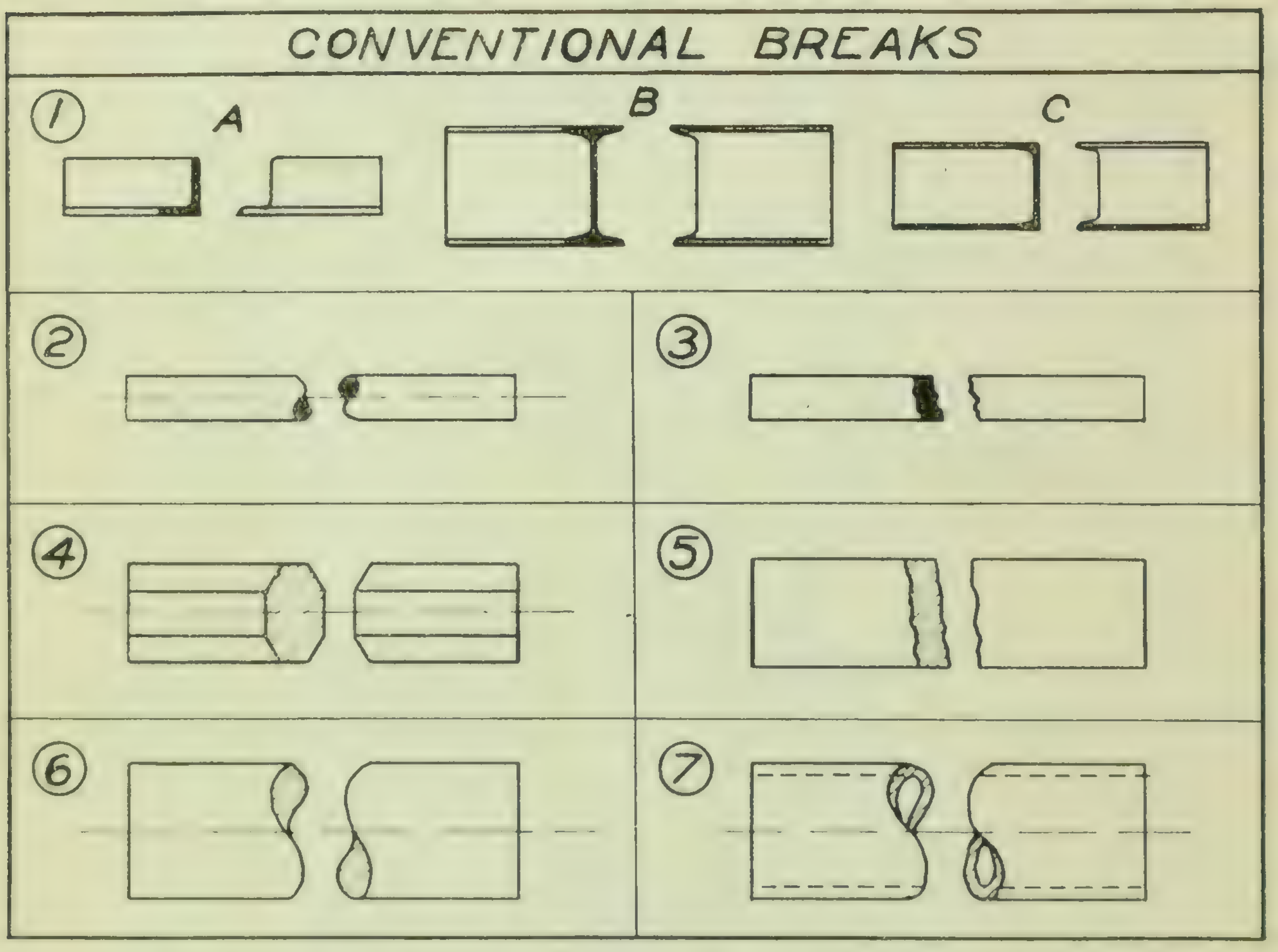
Note: If one side of cold rolled stock is machined before normalizing, the work will deform, because of the unequal strain caused by removing one work-hardened face.

Mild Steel. The samples shown are hot rolled and therefore have a black finish, approximately conforming to standard sizes and shape. This stock cannot be hardened, because the carbon content is too low, but it can be case-hardened if necessary. Mild steel is malleable and ductile and can be forged easily and drawn into tubes or wire, in addition to the rolled shapes shown. The formed shapes at the bottom of the diagram page are used for steel structures which are built up to form bridges, buildings, ships, etc., and parts are riveted together with soft iron rivets or welded.



Freehand Sketches

Exercise: On a 9″x12″ piece of paper, arrange the samples as shown to approximate sizes. Finish the sketches freehand with an HB pencil. Samples are drawn in oblique projection at an angle of 30°.



Structural steel conventional breaks are shown in diagram (1). (A) shows an Angle, (B) shows an I-Beam, (C) shows a Channel.

Small Round Rod is shown in diagram (2).

Small Square Bar is shown in diagram (3).

Octagonal Bar is shown in diagram (4).

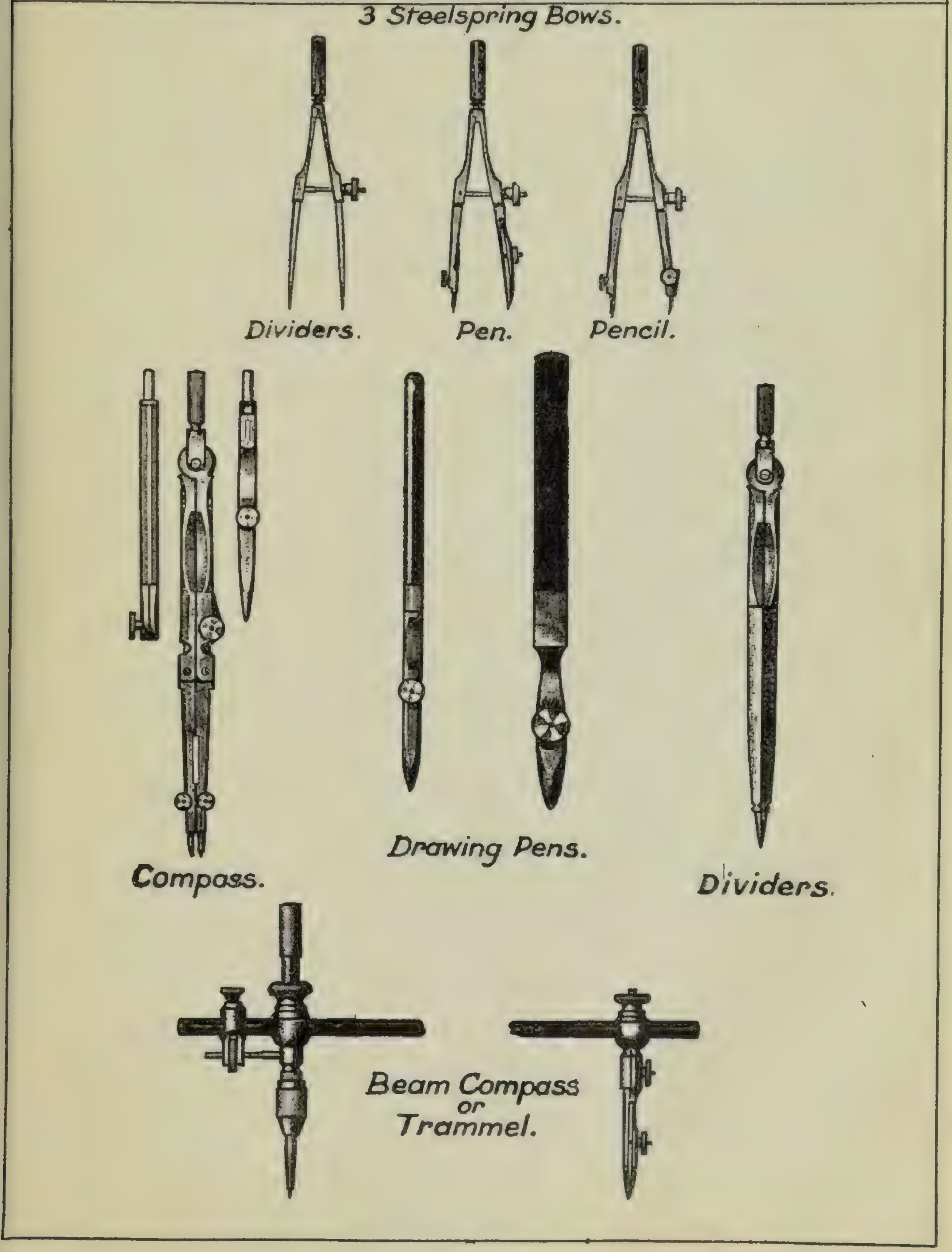
Square or Rectangular Bar is shown in diagram (5).

Large Round Rod is shown in diagram (6).

Pipe or Tubing is shown in diagram (7).

Note: In diagrams (1) to (3) the light cross-sectional parts are blocked in solid. In diagrams (4) to (7) the heavier cross-sectional parts are sectional lined according to the material from which the bars, rods, pipes, or tubes are made.

Exercise: On a 9″ x 12″ piece of paper arrange, sketch and name the breaks shown.



DRAWING INSTRUMENTS.

SCALES AND THEIR USES

The printed diagrams you are using in these lessons are printed to a scale of ⅝" to 1", or ⅝ full size. The drawings you make on a 9"x12" piece of paper are enclosed in a border which measures 8"x11". If you measure the printed diagram border size you will observe that it measures 5"x6⅞", so that it is ⅝ full size. If you are in doubt, therefore, about any measurements on the printed diagram sheet, you can find it by measuring with a scale of ⅝" to 1".

Scale Drawing is the procedure of drawing an object to a size other than its actual size. Always draw full size if it is at all possible.

Scale Full Size—This means that an object is drawn to its actual sizes or a scale of 1" to 1".

Reduced Scale—This means that an object is drawn proportionately smaller than the actual size.

Enlarged Scale—This means that an object is drawn proportionately larger than the actual size.

The Sizes of Scale Drawing must be the actual sizes of the object and not the "Scale" dimensions as measured by the scale.

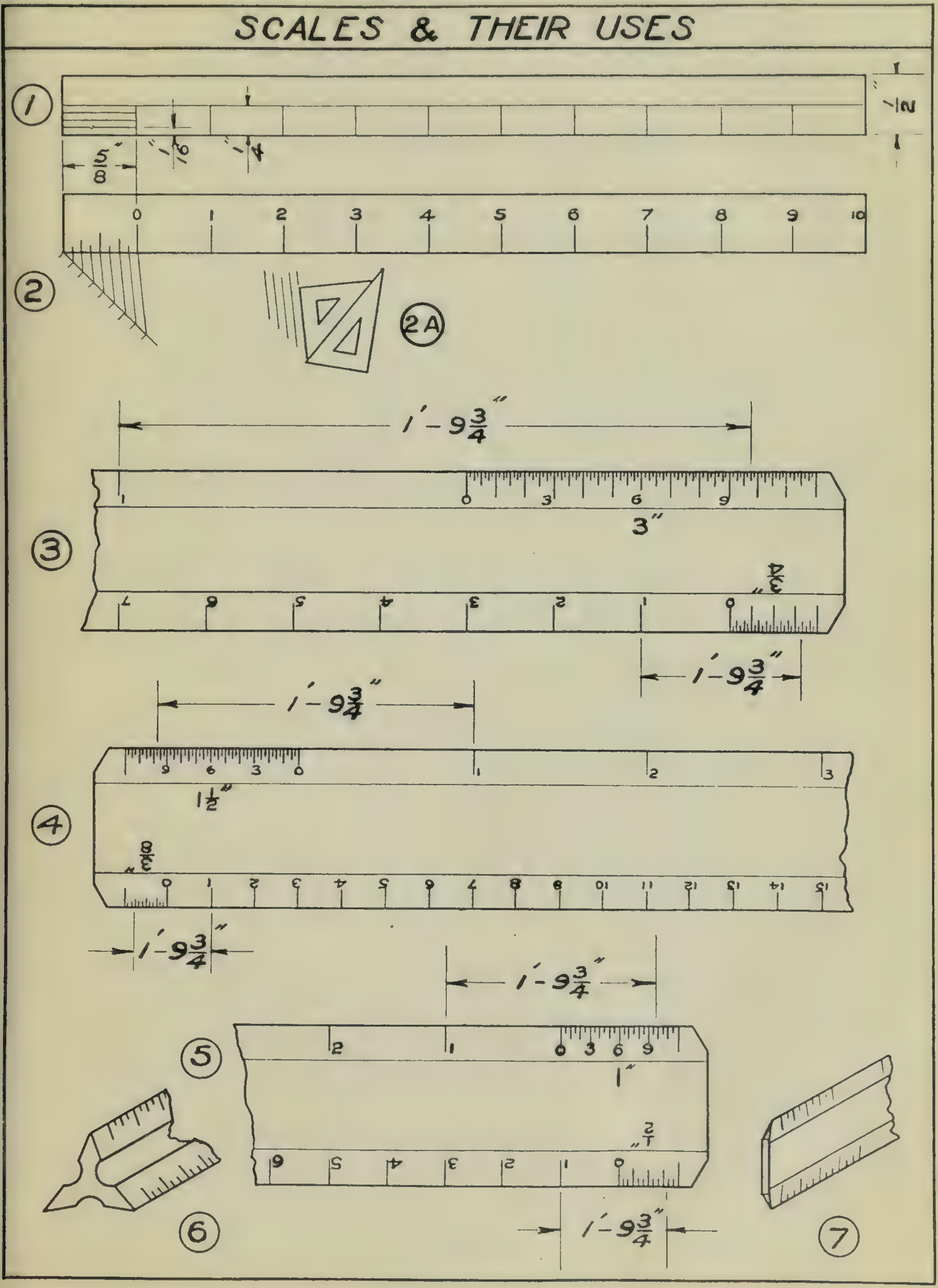
Example: An object is drawn to a scale of ⅝" to 1". The drawing of the object measures 8" with the ⅝" to 1" scale, but 5" with a full size scale 1" to 1". The dimension put on the drawing would be the actual size of the object, 8".

To Make a Simple Scale. Diagrams 1 and 2. The example illustrated here is a scale of ⅝" to 1" or ⅝ full size. Draw the guide lines as shown in diagram 1. To divide the end unit which is ⅝" long into 8 equal parts, first draw a line at any angle as shown in diagram 2. Mark along the sloping line any suitable 8 units of length such as ⅛" divisions. Use the 60° and 45° set squares as shown in diagram 2A, and join the end division to the (0) division. Now hold the 60° set square stationary and slide the 45° set square to obtain the parallel lines as shown. This will divide the ⅝" division into 8 equal parts to give ⅛ divisions on the ⅝" to 1" scale. To obtain tenths on a scale, a similar method would be used, by using ten divisions instead of eight.

Taking a Measurement from a Scale. This is shown in diagrams 3, 4 and 5. The end of the scales have the small divisions from the zero mark to the end of the scale. The measurements can be taken off directly from the scale to the paper, or by means of a pair of dividers.

Diagram 3 shows the measurement 1'—9¾" expressed as 1'—9¾" taken from a scale of 3" to 1'—0". Each unit representing one foot is divided into 12 main parts to give measurement in feet and inches. Each inch division is divided into 8 equal parts, to give measurement in eighths of an inch.

Diagonal Scale, Diagram 8. This type of scale is used when the divisions of a plain scale shown in diagram 2 become too small. The diagonal scale gives a greater degree of accuracy than a plain scale because it gives readings in tenths and hundredths of an inch. Horizontal reading in tenths; vertical reading in hundredths.


SCALES & THEIR USES
①
5/8"
1/2"
0 1 2 3 4 5 6 7 8 9 10
②
2A
③
1'-9 3/4"
0 3 6 9
3"
3/4"
④
1 1/2"
3/8"
⑤
1"
1/2"
⑥
⑦

The scales shown are:—

3″ to 1′—0″, diagram 3 or ¼ full size.
¾″ to 1′—0″, diagram 3 or 1/16 full size.
1½″ to 1′—0″, diagram 4 or ⅛ full size.
⅜″ to 1′—0″, diagram 4 or 1/32 full size.
1″ to 1′—0″, diagram 5 or 1/12 full size.
½″ to 1′—0″, diagram 5 or 1/24 full size.

This is called the representative fraction of full size and is obtained as follows:—

Representative fraction of scale

$$\frac{1\tfrac{1}{2}'' \text{ to a foot}}{12'' \text{ or 1 foot}} = \tfrac{1}{8}$$

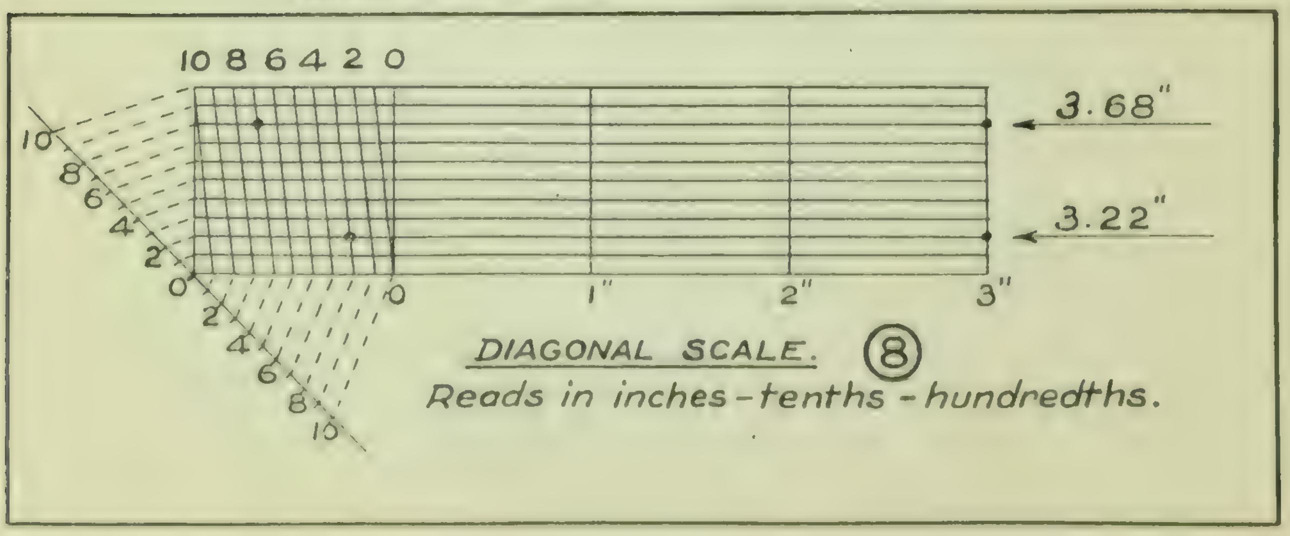
Divide the scale value by the full size value.

Types of Scales—These are shown in diagrams 6 and 7. The bevelled edges allow one to get the divisions close to the paper, so that the measurements can be accurately made. The best scales are made of ivory, but boxwood scales are quite satisfactory and are much cheaper.

Note: A single accent (′) denotes **feet,** and a double accent (″) denotes **inches.**

Exercise: On a 9″x12″ piece of drawing paper, draw the following scales with sufficient divisions to conveniently suit the border size 8″x11″.

(a) ⅝″ to 1″ scale, or ⅝ full size.
(b) ¾″ to 1″ scale, or ¾ full size.
(c) 1¼″ to 1′—0″ scale, or 5/48 full size.
(d) 2″ to 1′—0″ scale, or 1/6 full size.
Make the scales similar to that shown in diagrams 1 and 2.
(e) Draw a diagonal scale similar to the one shown in diagram 8. Show by two dots readings of—(a) 2.57″; (b) 3.79″.



DIAGONAL SCALE. ⑧
Reads in inches-tenths-hundredths.

FIRST AND THIRD ANGLE PROJECTION

It is assumed that a student has already taken a course in Geometry and Principles of Projection before starting this course of "Progressive Lessons in Engineering Drawing." If this has not been done it is suggested that the student proceed at once with the study of "Progressive Lessons in Drafting", which is one of the fundamental books required in this Technical series. This lesson will deal with the 1st and 3rd angle with a practical application of the important principles involved.

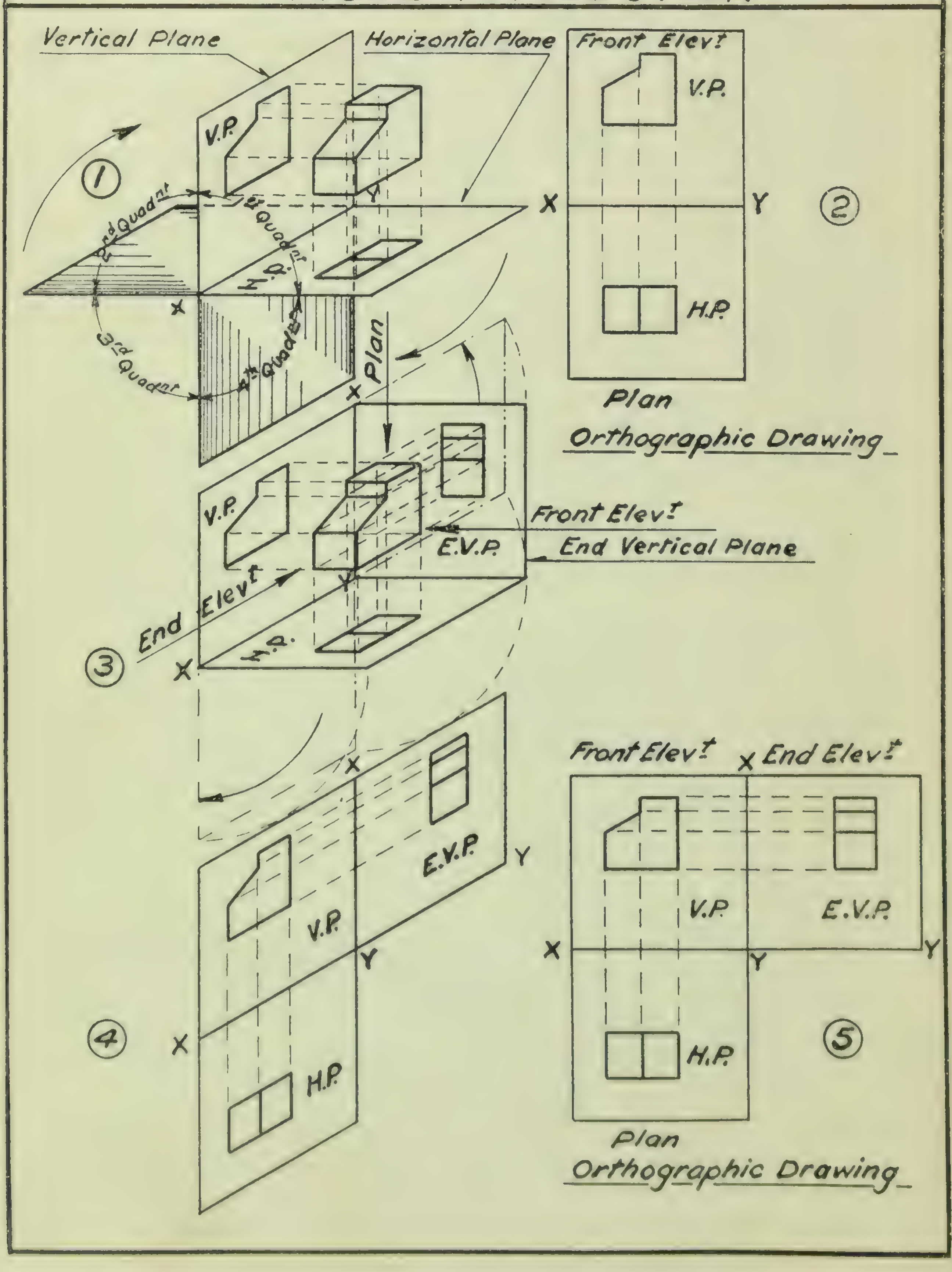
Orthographic Projection. Solid objects may be represented on paper in various ways. If projectors from a solid to the plane are perpendicular to the plane, the projection or view is called an **Orthographic Projection.** Two projections of a solid are usually needed to represent it completely, while in some cases three or four projections may be required.

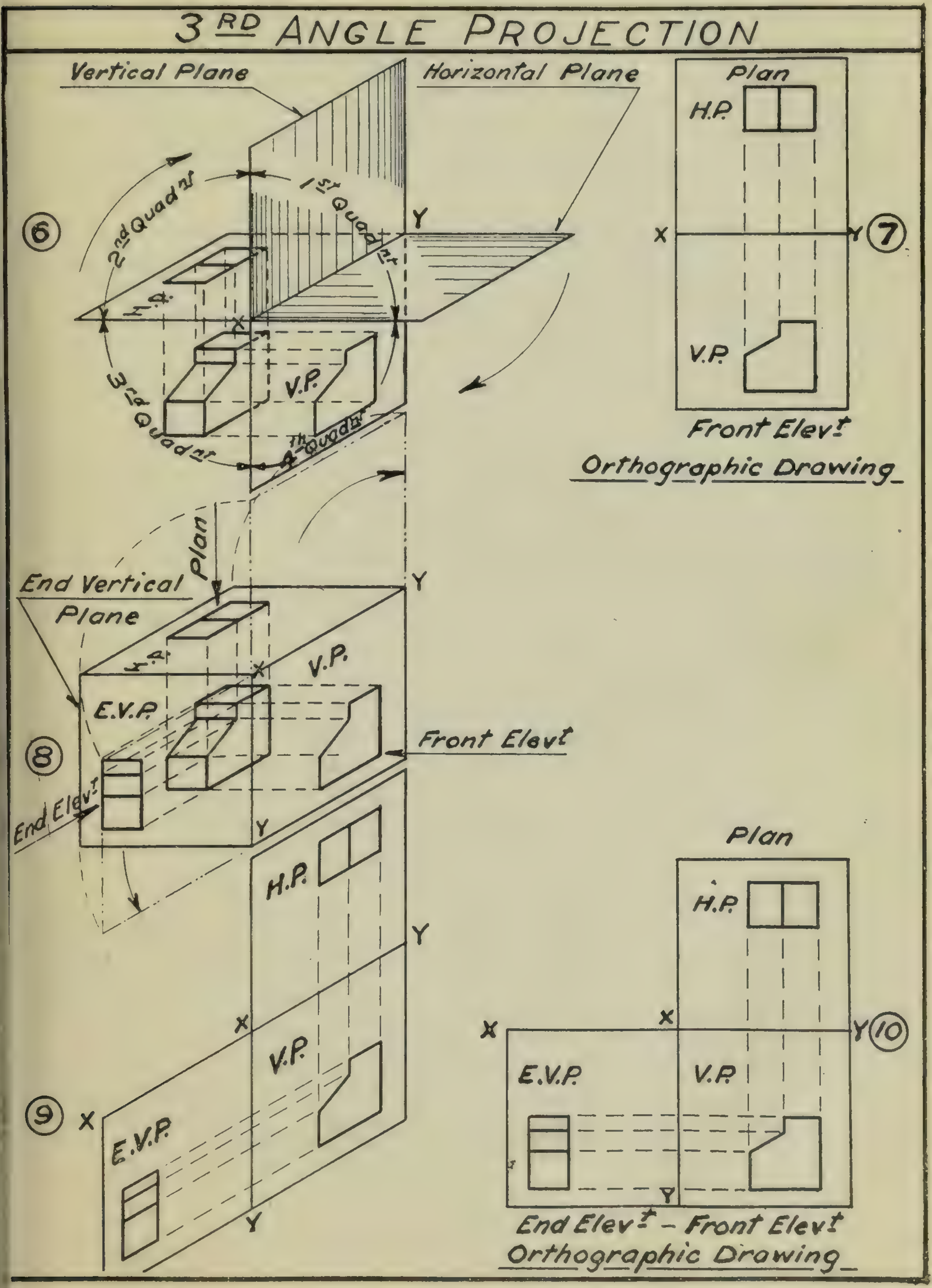
Diagram 1 shows a simple solid projected on to the horizontal and vertical planes. These planes form the 1st quadrant of the four quadrants shown, which will be referred to later. If the horizontal and vertical planes were represented by a sheet of paper folded at right angles to each other and the projections were drawn as shown, then the front view would be known as the **Front Elevation,** and the top view the **Plan.** If the paper is now flattened as in diagram 2, the relative positions of the plan and front elevation would be as shown. The line representing the meeting place of the planes is called the XY line.

1st Angle Projection. When views or projections are made from an object placed in the 1st quadrant as in diagram 1, the system of projection is called **1st Angle Projection.** Diagram 3 shows three views of an object drawn by 1st Angle Projection. This system has been called the British system because it has been largely used in Great Britain, but in some cases the British are now adopting the 3rd Angle Projection (diagrams 6 to 10), which has been called the American system, because of its use on that continent. Three planes are used in diagram 3 to obtain three views of the block as shown. When the planes are stretched out as in diagram 4 and 5, the relative position may be seen. The plan is shown on the H.P. (Horizontal Plane) and above the Front Elevation is shown on the V.P. (Vertical Plane). The End Elevation is shown on the E.V.P. (End Vertical Plane), and is the view looking in the direction of the arrow marked End Elevation in diagram 3.

3rd Angle Projection (Diagrams 6 to 10). The 3rd quadrant is used to obtain 3rd Angle Projection as shown in diagram 6. It is supposed that the planes are transparent so that when viewing the object the transparent planes lie between the eye of the observer and the object. If the H.P. and V.P. in diagram 6 are stretched out flat as in diagram 7, it will be observed that the plan is above, and the elevation below the XY line. This is the opposite position from that obtained by 1st Angle Projection. (Diagram 2.)

1ST ANGLE PROJECTION




3RD ANGLE PROJECTION
Vertical Plane
Horizontal Plane
⑥
2nd Quadnt
1st Quadnt
H.P.
Y
X
3rd Quadnt
V.P.
4th Quadnt
Plan
H.P.
X
Y ⑦
V.P.
Front Elevt
Orthographic Drawing
Plan
End Vertical Plane
Y
H.P.
X
V.P.
E.V.P.
⑧
Front Elevt
End Elevt
Y
H.P.
Y
X
V.P.
⑨
X
E.V.P.
Y
Plan
H.P.
X
X
Y ⑩
E.V.P.
V.P.
Y
End Elevt – Front Elevt
Orthographic Drawing

Transparent Planes. Transparent planes are shown enclosing an object in diagram 8. If the object is viewed from the outside of this glass-like box, and the outline is drawn on the surface of the box, then the positions may be found. When the planes which form the enclosure are stretched out as in diagrams 9 and 10, the relative positions may be seen. Note particularly that each view is adjacent to the side viewed. In 1st Angle Projection each view is adjacent to the opposite side to that viewed.

Comparisons Between 1st and 3rd Angle Projection.

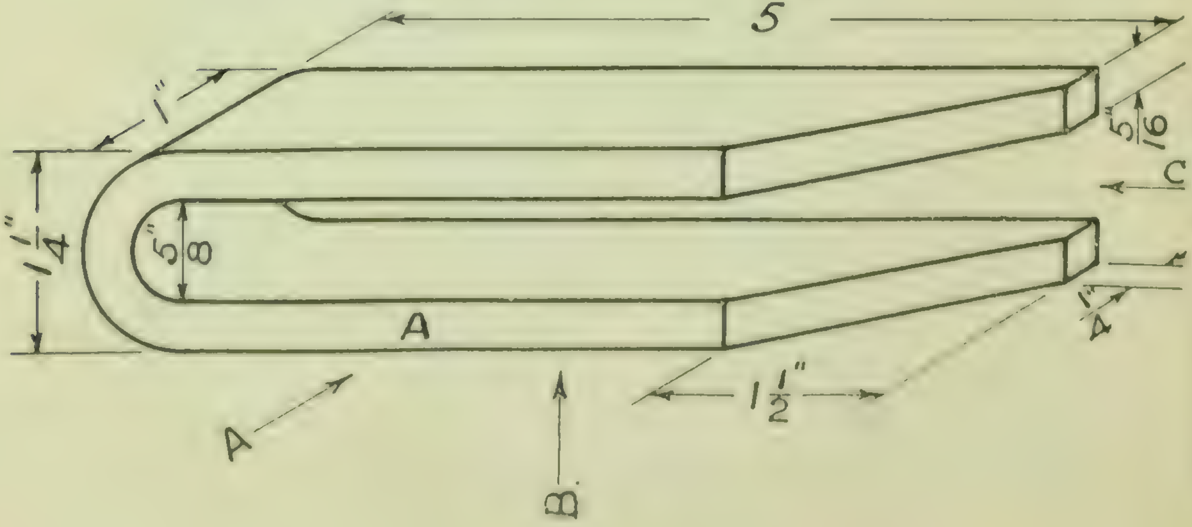
The two systems of projection are shown drawn out on adjacent pages so that the student may have the opportunity of comparing one system with the other. Compare diagram 2 with diagram 7, and diagram 5 with diagram 10. Most of the illustrations in this course of lessons are drawn by the 3rd Angle method, because when objects, with complicated form and varied detail, have to be represented, it is easier to read. The main reason for this is the fact that each view is adjacent to the side viewed, and each detail may be easily connected between views when reading the drawing. To summarize this, one might say that in 1st Angle Projection the view lies beyond the object, diagram 3. In 3rd Angle Projection the view lies between the observer and the object, diagram 8.

Exercise: On a 9″x12″ piece of drawing paper draw the clamping bar shown below as follows: (Scale full size.)

(a) Three views drawn by 1st Angle Projection on upper part of the sheet, without dimensions.

(b) Three views drawn by 3rd Angle Projection on the lower part of the sheet, without dimensions.

Note: First place the clamp in its natural used position (face A on top), then draw plan view A, front elevation B, end elevation C.



THE USE OF LINES AND FIGURES

Good drawings are made by paying close attention to small details. One can see at a glance the touch of the experienced draftsman by the character of the work. This lesson is very simple and elementary yet it is very important, and unless these simple details are mastered by repetition until the standard is reached, the character of all the drawings produced afterwards will be affected.

Outline (diagram 1). The line representing the outline or edge of a part must be bold, for tracing it should be about 1/32″ thick.

If the drawing is held at arms length the outline should predominate over every other line, as it represents the essential form of the job which must not be mistaken.

All other lines must be subservient to the outline.

Projectors (diagram 2). These lines are made thin and must not touch the outline, so that they may never be mistaken for the outline—a space between the projector and the outline of 1/16″ is suitable.

Hidden Parts (diagram 3). Those parts that are beneath the surface of the job must be represented to show their presence, shape, and location. The line used to represent hidden parts is usually made a broken line, ⅛″ line and 1/16″ space, to distinguish it from the outline.

Cutting Plane (diagram 4). If a section is to be represented, the cutting plane where the section is made is located by a cutting plane line which is usually made as shown in diagram 4. The arrows indicate the direction the section view takes.

Dimension Line (diagram 5). This line is made thin with a space about its centre, to provide room for the dimension. The arrow points must be very sharp or acute to give a smart clean cut appearance to the drawing.

Leader (diagram 6). The leader is a thin line which connects the notation or note to the place that the note refers to. Some draftsmen use a curved irregular line for this purpose as a contrast to the other straight lines, but the beginner will find the lines illustrated suitable. Draw the lines at any angle to suit the work and print the note on the horizontal part of it.

A one-sided arrow point is used to distinguish the leader from a dimension line.

Centre Lines (diagram 7). The centre line is a very important one in mechanical drawing as important distances are measured from centre to centre, and unless the centre distances are correct the other parts would not fit in the machine. If the drawing is complicated the centre line is marked to focus attention to it by the symbol shown.

Section Lines (diagram 8). These are drawn at 45° and spaced an amount according to the size of the drawing, the spacing should be regular. A simple template used inside the set square will give even spacing.

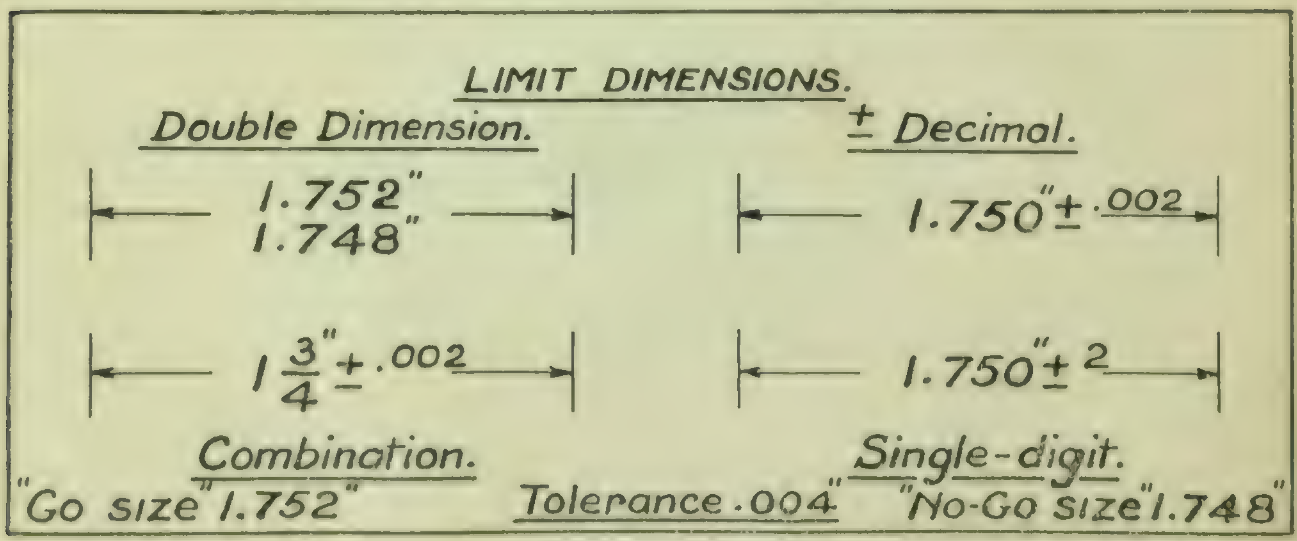
Lines of distinct type and grouping are used to indicate the material from which the part is made. (See page 35).

Dimensions (diagrams 9 to 14). Dimensions must be clear, there must be no possible doubt in the mind of a workman as to what the dimensions are on a drawing. Diagrams 9 and 10 may be read as 11/16″ or 1-1/16″ but diagram 11 is definitely 1-1/16″. The whole number is larger than the fractional numbers and is divided centrally by the fraction dividing line which is in line with the dimension line. Examples of dimensions and angles are shown in diagrams 12, 13 and 14 where different methods are adopted according to the space available.

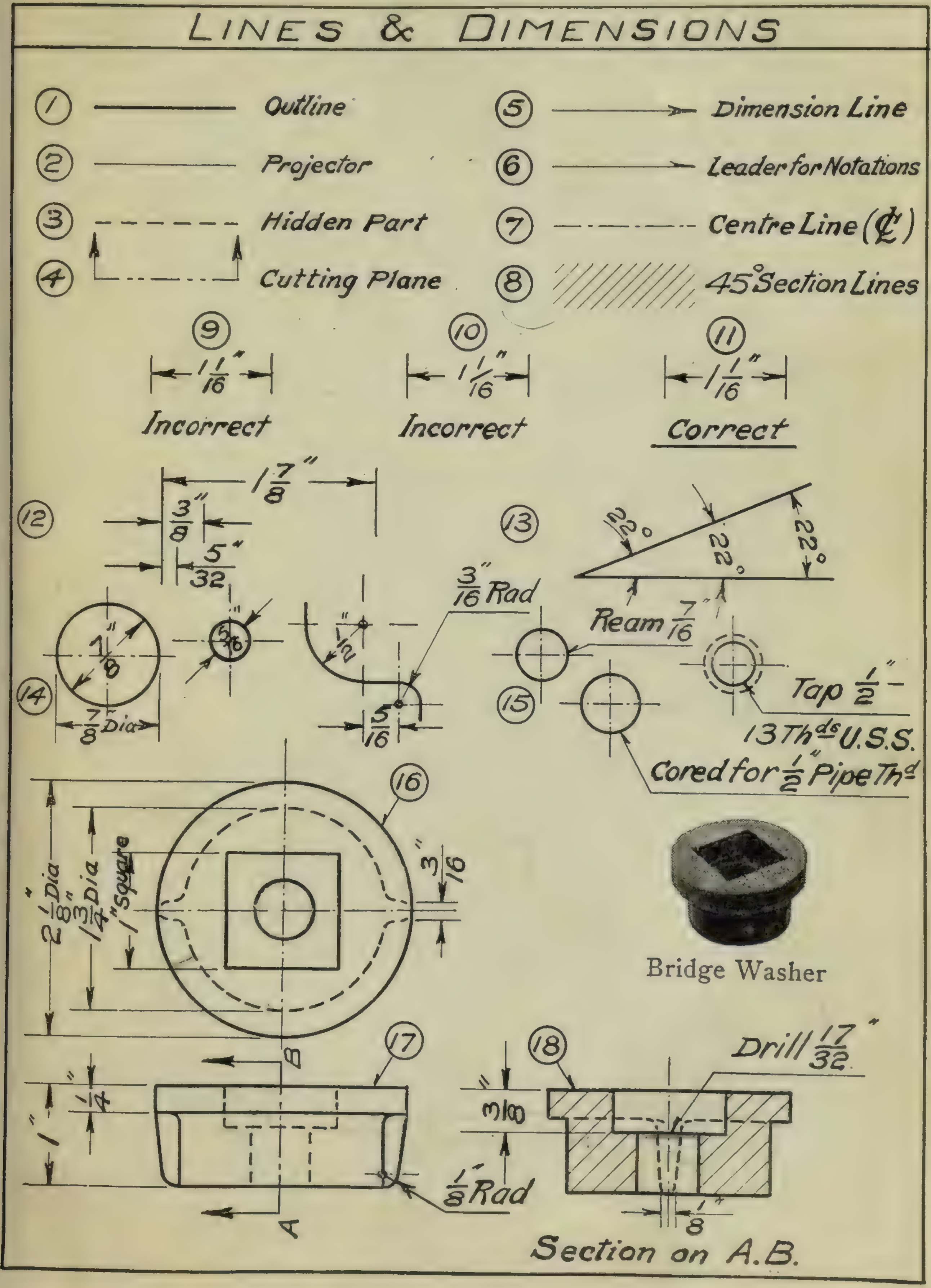
Notation (diagram 15). Notes or notations are often necessary in addition to dimensions to explain how a particular part is to be treated or operated upon. A hole as shown in the examples may be reamed, tapped or cored. (See pages 37 and 41).

Drawing Examples. A simple drawing of a cast-iron bridge washer (diagrams 16, 17, 18) serves to illustrate the application of lines, figures and notation as given in this lesson.

Exercise. On a 9″x12″ piece of drawing paper duplicate the lesson diagrams. Scale full size.



Samples of Limit Dimensions used for work made to definite limits of accuracy and tested by "Go" and "No Go" guages.


LINES & DIMENSIONS
1 Outline
2 Projector
3 Hidden Part
4 Cutting Plane
5 Dimension Line
6 Leader for Notations
7 Centre Line (℄)
8 45° Section Lines
9 1 1/16" Incorrect
10 1 1/16" Incorrect
11 1 1/16" Correct
12
1 7/8"
3/8"
5/32"
13
22°
22°
22°
7/8"
5/16"
1/2"
3/16" Rad
5/16
7/8 Dia
14
Ream 7/16"
15
Tap 1/2" - 13 Th^ds U.S.S.
Cored for 1/2" Pipe Th^d
16
2 1/8" Dia
1 3/4" Dia
1" Square
3/16
Bridge Washer
17
B
A
1/4"
1"
1/8" Rad
18
3/8"
Drill 17/32"
1/8"
Section on A.B.

STAGES OF MAKING A STRAIGHT LINE DRAWING

You are to be given an opportunity of making a pencil drawing to scale from an oblique drawing of an object. The stages on the diagram sheet are presented for your guidance, so that when you begin your own assignment you will know how to proceed. The object illustrated is a Vee-block and has a very simple form. It consists entirely of straight lines, therefore it is suitable for a beginner. The fundamental methods involved in starting to plan this simple drawing can be applied to other drawings later.

The Isometric drawing in the right-hand corner of the diagram gives all the necessary information about the form and size of a Vee-block, which is drawn in stages.

Starting a Drawing.

1. Fasten the drawing paper to the drawing board with the top left-hand pin.
2. Move the paper (pivoted about the pin) until the top edge is parallel with the tee square blade while the stock is held securely against the board.
3. Place the pins in the three remaining corners of the paper.
4. Draw the 4 border lines ½″ from the edge of the paper.
5. Measure ⅜″ below the top border line and draw a line to provide space for the heading.

Stages of the Drawing (For pencil finish only).

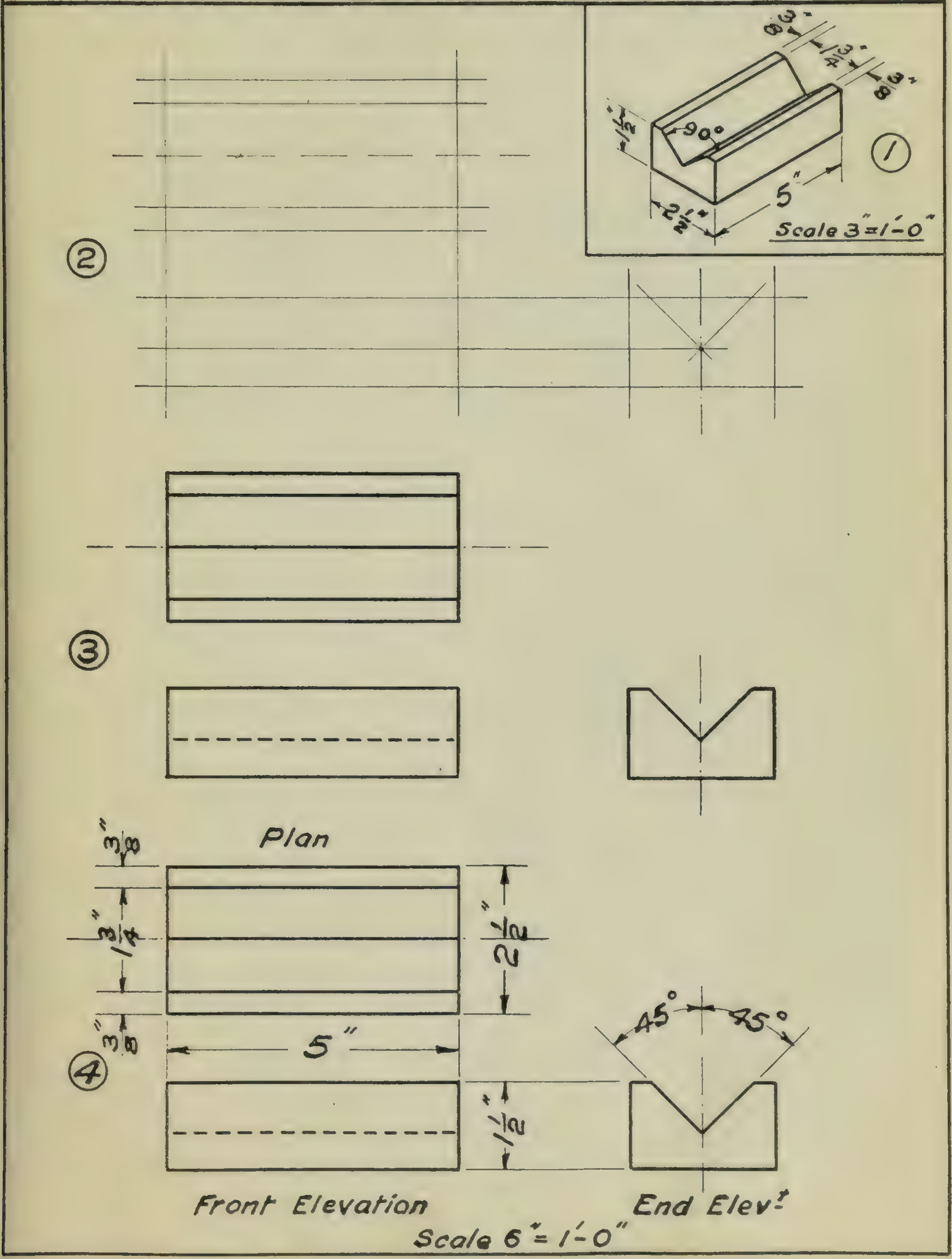
In this example three stages of making a drawing are shown.

1. Space the drawings (see note below).
2. Draw light construction lines with a hard sharp pencil (Diagram 2).
3. Erase lines not to appear in the finished drawing.
4. Line in outline with a bold dark line (Diagram 3).
5. Put in centre lines, projectors, dimension lines, figures and printing in the order mentioned.

Spacing the Drawings.

This is sometimes known as "blocking in the views" and is very important. You must know how many views are required in the completed drawing and what scale they are to be drawn to. With this information measure off the drawing space between the border to see how the views will fit in. You will note that each stage is separated by a greater space than that between the plan and elevation because the plan and elevation are related to each other and the stages are distinctly separate.

STAGES OF STRAIGHT LINE DRAWING

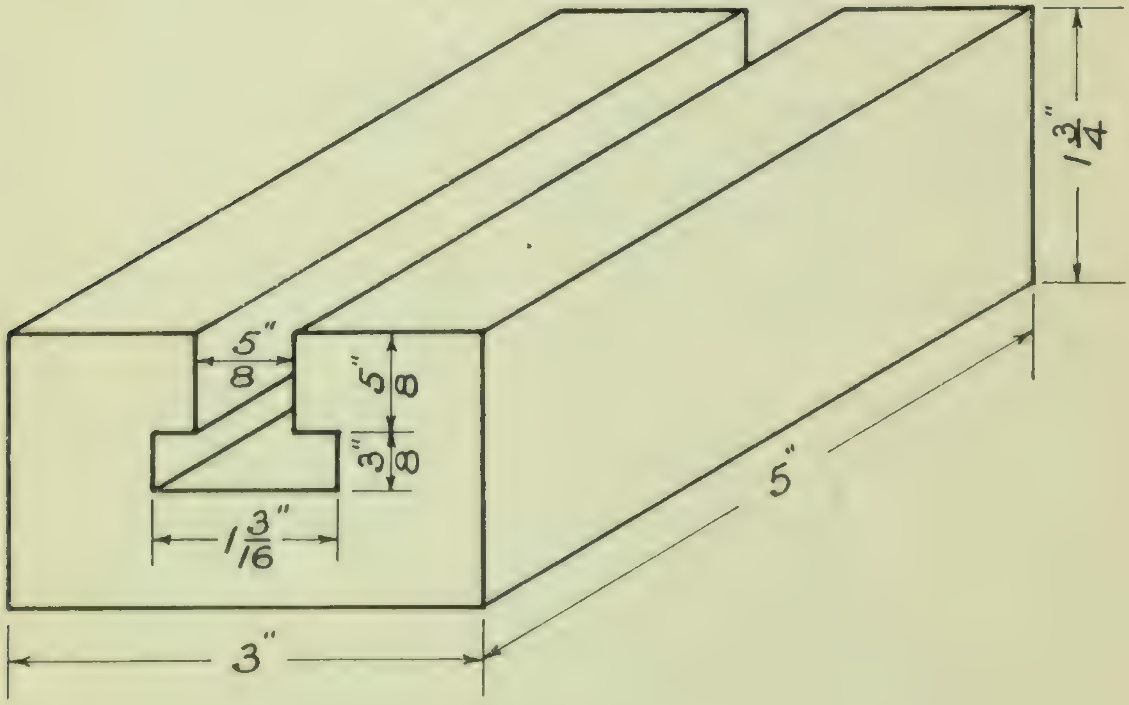


Procedure for Drawing.

The adjacent diagram sheet is divided into 3 stages. Construct all stages with light pencil lines at the same time. Do not draw one view at a time when the same line can be continued to form part of another view. This procedure will save time and give true projection to the views.

Exercise:—Tee slotted block shown in oblique projection.

On a 9″x12″ piece of paper draw three stages of a drawing of the given Tee slotted block showing plan, front elevation and end elevation. Your sheet will be similar to the diagram sheet of the Vee-block except that the Tee slotted block will take the place of the Vee-block. In the last stage put in all dimensions and name the views. Scale 6″=1′—0″.



RULES FOR DRAWING

The following rules are used in many drawing offices as standard practice and are working out very effectively.

1. All dimensions indicating horizontal measurements should be parallel with the lower edge of the drawing, so they may be read from a position directly in front of the drawing.

2. Dimensions indicating vertical measurements should read from right-hand end of drawing.

3. If the upper end of an inclined line leads towards the right, the dimension should read from the right. If it inclines toward the left, it should read from the left.

4. Dimensions up to and including two feet should be given in inches. If over two feet, they should be indicated as feet and inches.

5. Arrow points should be placed at both ends of the dimension line.

6. Do not place more than one dimension on any one line.

7. Never place the dimensions on a centre line, or on a contour line of the drawing itself.

8. Do not place a dimension on the intersection of two lines.

9. If the dimension must be placed on a cross-hatched surface, leave an open space in the hatched section for the figures.

10. Over-all dimensions should always be given, as well as detailed dimensions of parts.

11. Do not crowd a dimension into a space which is too narrow for the figures.

12. Always place a dash between feet and inches.

13. When a measurement is to be taken with great accuracy, the fraction of an inch should be given in decimals.

14. Over-all dimensions for patterns, for furniture and architectural work should always be given in feet, inches and fractions of an inch.

15. All figures should be neatly printed and not hurriedly written.

16. Dimensions must indicate the actual size of the piece itself, regardless of the scale to which the drawing is made.

OBLIQUE AND ISOMETRIC DRAWING

Reference has already been made to the above methods of drawing in the lesson on "Methods of Representing an Object." The orthographic drawing of the block shown in diagram 1 is taken as an example for representation by Oblique and Isometric drawing.

Oblique projection. Diagram 2 shows one method of representing the block. The front face of the block is a true elevation as it is shown in diagram 1. The sides are drawn at 45° in diagram 2, and 30° in diagram 3. Either method may be used to suit the object being represented. The thickness of the block is measured along the lines as shown in diagrams 2 and 3. This has a tendency to make the object look thicker than it actually is, for this reason the draftsman may reduce the length of the angular lines but the dimensions must indicate the correct dimensions of the object required to be made. The centres of the circles in the front view of the block are projected at the same angle as the sides, to locate the depth and centres for the recesses.

Isometric projection. Diagram 4 illustrates the method involved in representing an object in Isometric. If a square block is to be drawn, no face will present a true view. Vertical edges in the object remain vertical but the sides will be drawn at an angle of 30°. All dimensions are made along the lines which may be vertical or at 30°.

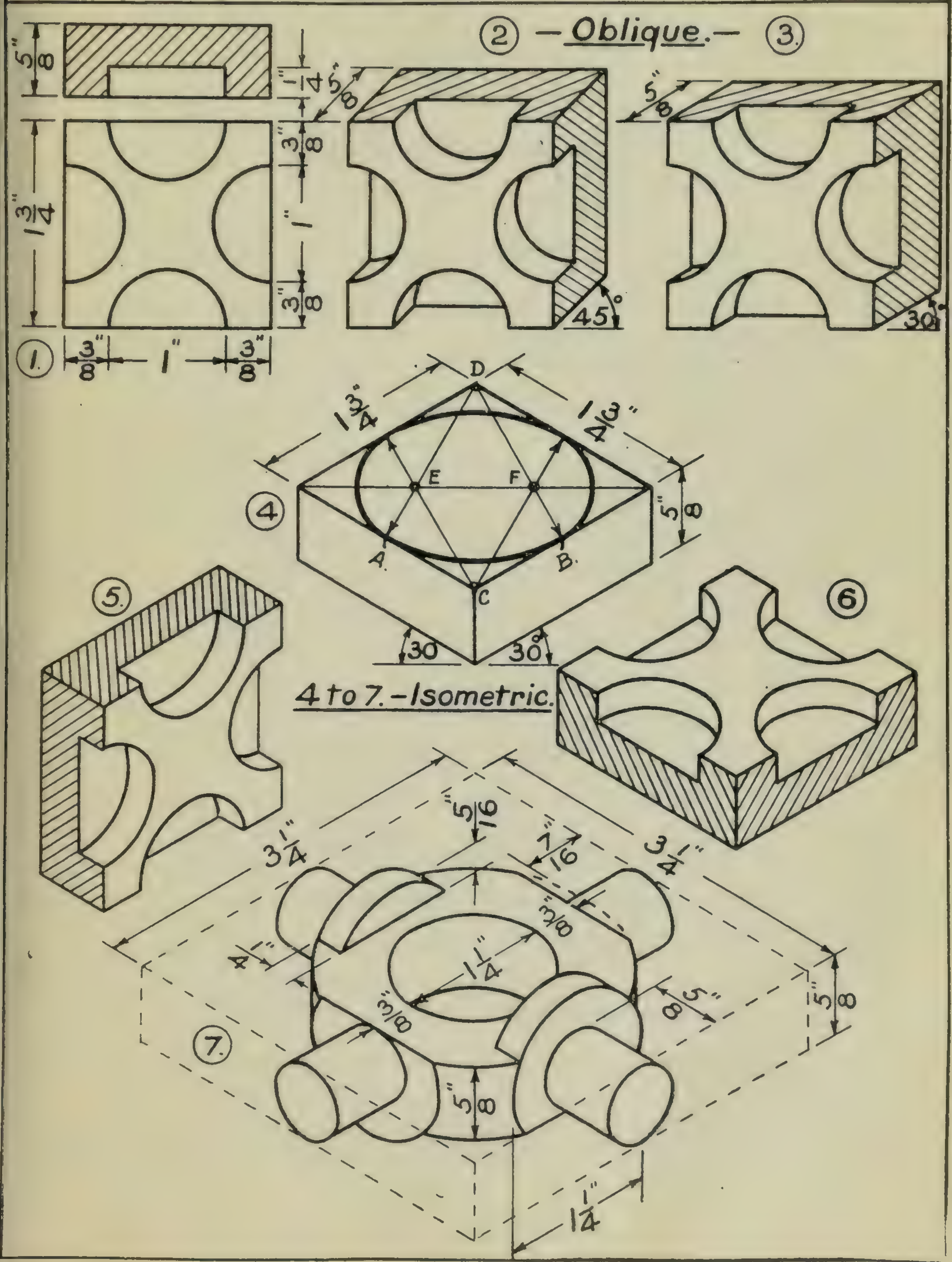
To draw a circular object in Isometric. An Isometric drawing is first made of a square which would enclose the circular object as shown in diagram 4. The diagonal of the Isometric square is drawn, this becomes the major axis of an ellipse, which represents the circle in Isometric. To draw this ellipse with a compass, first draw lines from the corners of the square to the centres of the opposite sides as shown at DA, DB, etc. These lines intersect the major axis of the ellipse at E and F. With E as centre and EA as radius, draw the end of the ellipse, proceed in the same manner at the other end. With D as centre and DA as radius, draw the arc AB. Finish the other arc in the same way. This ellipse is the Isometric drawing of a circle as it appears on the top face of the block. Diagram 5 shows the Isometric view of half circular recesses on the vertical face of the block shown in diagram 1. The same method of drawing the ellipse is applied after first drawing the Isometric view of the square that encloses the circle. Diagram 6 shows an Isometric view of the block as drawn in diagram 1 with the half circular recesses on the top face.

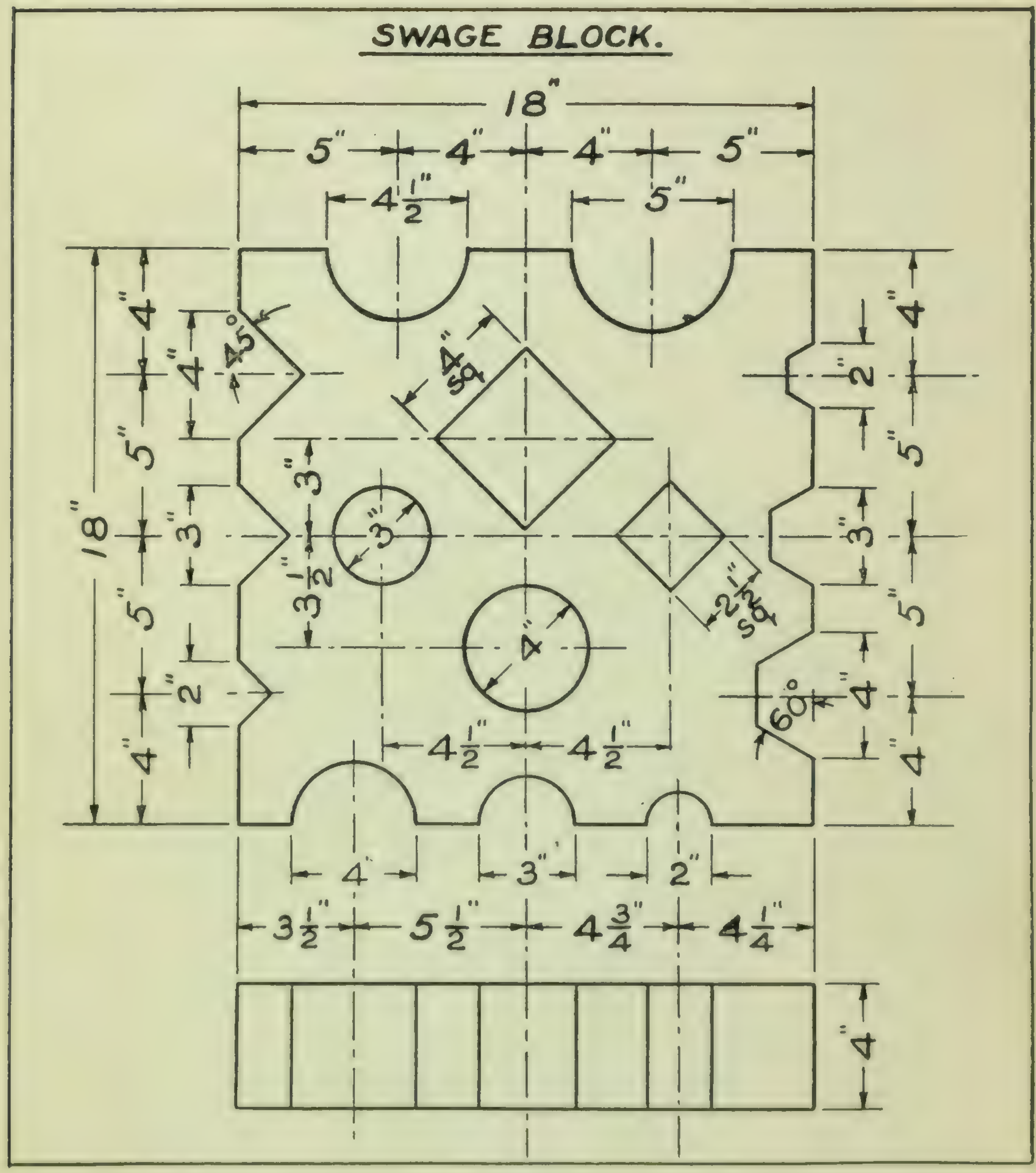
Isometric drawing of a universal joint spider or knuckle, diagram 7. The dotted lines show the Isometric square that encloses the 4 pins of the object. The drop forged form of an actual spider or knuckle has been simplified for drawing purposes.

Exercises.

1. On a 9" x 12" sheet of drawing paper draw the Oblique and Isometric drawings as shown in diagrams 2, 3, 4, 5, and 6. Scale full size.
2. On a 9" x 12" sheet of drawing paper draw the Isometric view of the universal spider shown in diagram 7, and put in dimensions. Scale twice full size

OBLIQUE AND ISOMETRIC DRAWING.





3. On two 9" x 12" pieces of drawing paper, draw the Swage Block, Scale 3" = 1'—0": (a) In Oblique Projection; (b) In Isometric.

SECTION DRAWINGS

It is not always possible to give full information on a drawing by outside views only. If the object is cut open the interior is revealed showing the construction of the inside. This is accomplished in drawing by sectional views which consist of cutting through the object with cutting planes at the location desired. The surface which is produced by cutting a solid is called a **section.** If any parts are seen beyond the cutting plane the view is called a **sectional elevation** or a **sectional plan.**

Section Lines. Diagrams 1 to 7 are drawn at 45°, usually inclined towards the right-hand. Different lines and different groups of lines represent certain materials used in construction, so that by looking at the section lines on a drawing one can decide what materials are to be used. Sometimes the simple arrangement shown for Cast Iron is used for other materials. The material is printed in the section lining in abbreviated form as illustrated in diagram 1.

Use of a Cutting Plane. Diagram 10. The shaded cutting plane (B) is shown cutting through a simple block with a brass bushing. The front part (A) would be removed leaving the part shown by dotted lines beyond the cutting plane. The part to be drawn in section is shown in diagram 11 as an Isometric view of one-half of the block. The **sectional elevation** is the view looking in direction of the arrow (A) and is represented in diagram 12 as an Orthographic drawing. Notice particularly that the back part of the block is shown because it is seen in elevation beyond the cutting plane.

Direction of Section Lines. In diagram 12 the lines showing the section of the Cast Iron block are drawn in the same direction, while the section lines for the bushing are drawn in the opposite direction, with less space between them for a smaller surface.

Half Sectional Elevation. If two cutting planes A and B are used as in diagram 13, one-quarter of the block is removed as shown in the Isometric drawing diagram 14. If a view is now taken of the block in the direction of the arrow, (A) diagram 14, an Orthographic drawing of the block is produced (diagram 15) showing the left half in outside elevation and the right half as a sectional elevation. This method is often used to show the outside and inside of an object in one drawing.

Sections of a Rivet Joint. Diagrams 16 and 17. These illustrations show that when a sectional view is taken, the solid inside part is left whole, as nothing would be learned by cutting through an internal solid part. Diagram 16 shows the sectional elevation through the hole in the plates before the rivet is put in position. Note particularly the back lines beyond the cutting plane. Diagram 17 shows a sectional elevation with the rivet in position, left whole.

Half Sectional Elevation of Bridge Washer and Bolt. Diagram 18. This drawing shows the use of a Bridge Washer as drawn in detail on page 25. This is an application of a section drawing in an assembly drawing. Notice particularly the solid line showing where the section plane has cut to expose the bolt which is left whole, showing how the bridge timbers are bolted together.

Exercises: Arrange and draw the following on a 9″x12″ sheet.

(1) Draw given section lines, diagram 1 to 9.

(2) Draw a sectional elevation, diagram 12. Scale half full size.

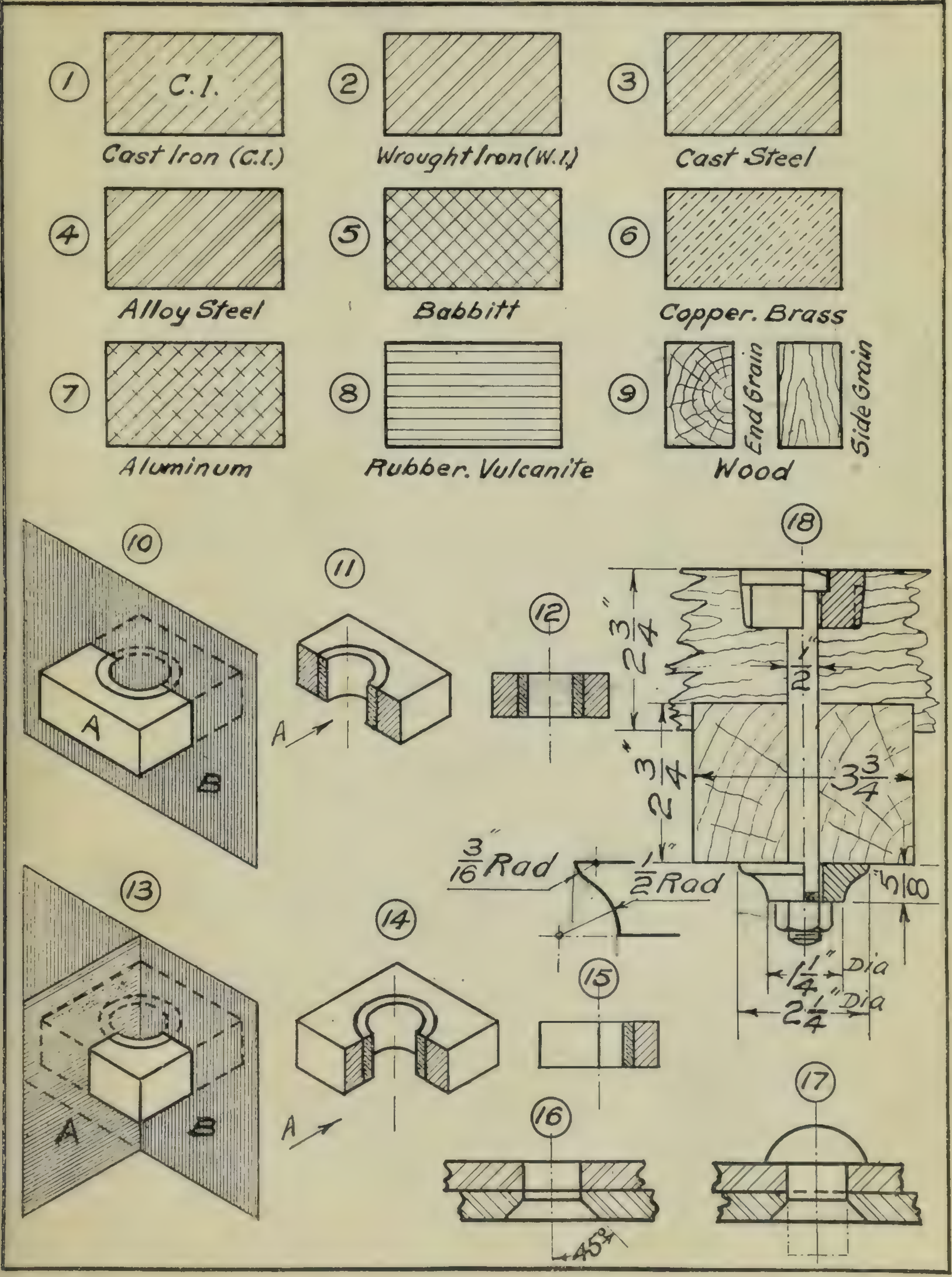
(3) Draw a half-sectional elevation, diagram 15. Scale half full size.

Note. Size of the Cast Iron block, 4″ square x 1½″. Bore of block 2¼″, bore of bushing 1½″.

(4) Draw the rivet joints, diagrams 16, 17, thickness of plate ¼″, diameter of rivet ½″ (see page 45). Scale full size.

(5) Draw a half sectional elevation of diagram 18, for size of Bridge Washer (see page 25). Scale half full size.

SECTION DRAWINGS



NOTATIONS FOR TOOL OPERATIONS

To draw intelligently, one should possess a conviction provided by practical experience with the material objects represented in the drawings. In a lesson such as this, suggestions of a few practical operations are offered to present the idea that a draftsman should make himself familiar with shop conditions and, better still, train himself, if possible, by carrying out the basic operations involved in his work.

Isometric Drawings of Tool Operations

These are presented in the adjoining diagrams with a threefold objective.

(1.) To represent the effect of the given operations on metal.

(2.) To show notations which denote the operations.

(3.) To give the student an opportunity of making isometric drawings with celluloid templates.

Three templates are required to duplicate the curves represented. After laying out one curve of each size, take a piece of celluloid and place it over the drawing. Scribe the line with a sharp scriber and cut out the shape. Finish the edge smooth with a file or abrasive cloth.

Reducing to a shoulder (Diagrams 1 and 3). This operation may be carried out on a lathe with a tool bit or hollow mill. The neck shown in diagram 3 is cut to provide thread clearance.

Drilling a centre hole (Diagram 2). Work is drilled in this manner with a combination drill with a 60° countersink, for mounting work on the centres of a lathe.

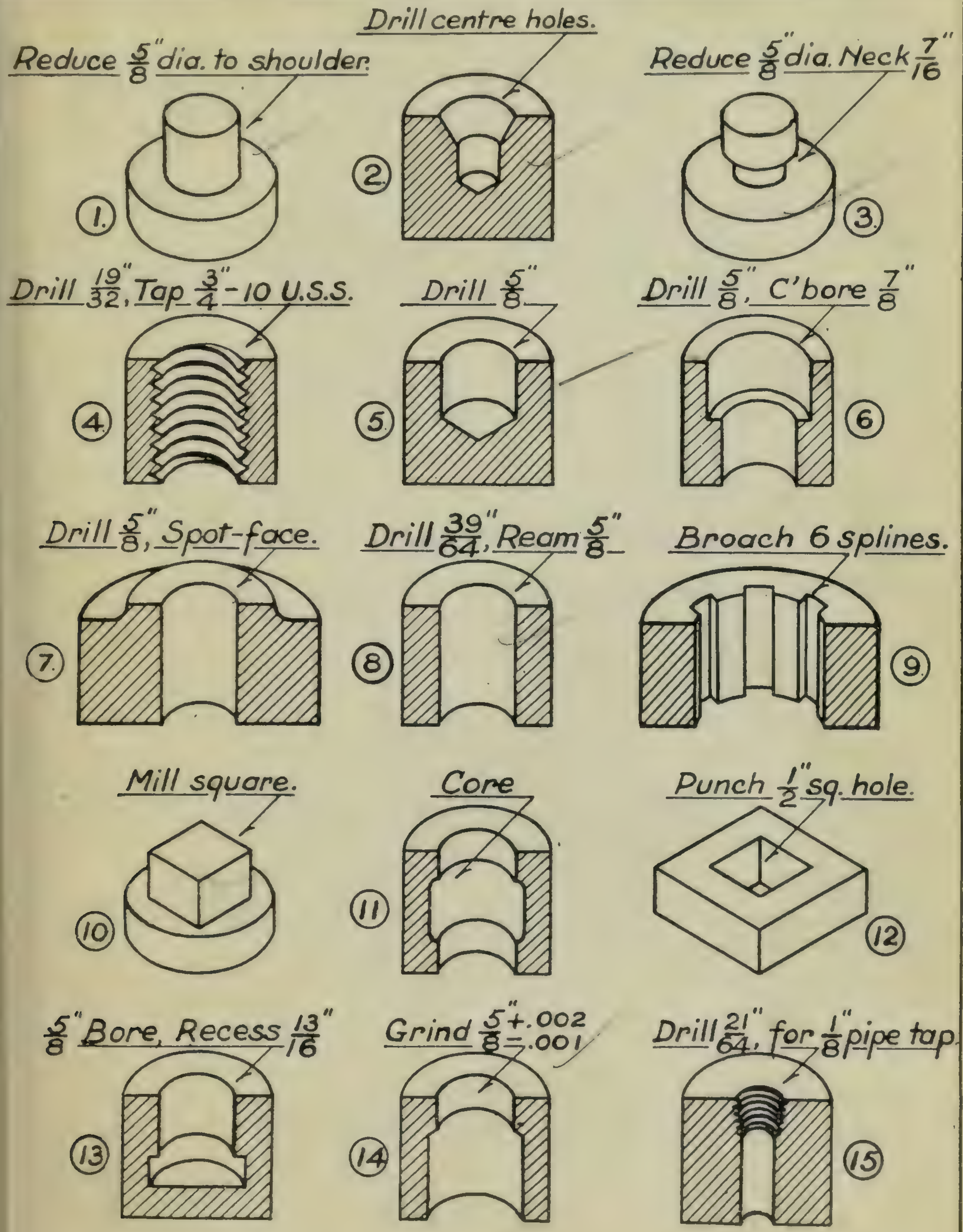
Drilling and Tapping (Diagram 4). Tap drill size is usually slightly larger than the root diameter of a thread, to provide generally for easy tapping to give about 75% depth of thread.

A drilled hole (Diagram 5) shows the conic recess made by the 118° drill point. A drill rarely drills a hole perfectly, and is not considered accurate when fine limits are required.

A reamed hole (Diagram 8). A reamer corrects the inaccuracies of a drill. It produces round holes and accurate holes to .001″ limits in addition to producing a smooth surface on the metal which is left rough by a drill.

A counterbored hole (Diagram 6). This operation may be performed on a drill press or a lathe to enlarge a hole previously drilled.

NOTATIONS FOR TOOL OPERATIONS.


Reduce $\frac{5}{8}''$ dia. to shoulder.
1.
Drill centre holes.
2
Reduce $\frac{5}{8}''$ dia. Neck $\frac{7}{16}''$
3.
Drill $\frac{19}{32}''$, Tap $\frac{3}{4}''$-10 U.S.S.
4
Drill $\frac{5}{8}''$
5
Drill $\frac{5}{8}''$, C'bore $\frac{7}{8}''$
6
Drill $\frac{5}{8}''$, Spot-face.
7.
Drill $\frac{39}{64}''$, Ream $\frac{5}{8}''$
8
Broach 6 splines.
9.
Mill square.
10
Core
11
Punch $\frac{1}{2}''$ sq. hole.
12
$\frac{5}{8}''$ Bore, Recess $\frac{13}{16}''$
13
Grind $\frac{5}{8}''{}^{+.002}_{-.001}$
14
Drill $\frac{21}{64}''$, for $\frac{1}{8}''$ pipe tap.
15

Spot facing (Diagram 7). A cast boss would have a rough, irregular surface. Spot facing is usually done on a drill press to make a smooth bearing surface at right angles to the axis of the hole.

Broaching (Diagram 9). After a hole is bored, a long broach made of hardened and tempered tool steel is drawn through the hole. The teeth on the broach are tapered to cut gradually in one operation the splines required.

Mill Square (Diagram 10). This operation is usually carried out on a milling machine, the work may be milled with round corners by cutting off one-eighth of the diameter of the milled part, or with sharp corners by cutting off one-seventh of the diameter of the milled part.

Punch ½″ square hole (Diagram 12). This example is given to show that certain metals up to a limited thickness may have holes of various shapes quickly formed by the use of a punch press.

Core (Diagram 11). Interior shapes may be formed in cast metals by placing a sand core (which is made in a core box) in the mould so that the molten metal surrounds it and leaves the space required. It saves time in machining and saves metal.

Boring a recess (Diagram 13). This recess is usually cut on a lathe to provide a clearance for an internal thread or other operations.

Grinding to limit sizes (Diagram 14). This operation provides a smooth finish and a concentric hole with accurate limits of size. The "Go" size would be ⅝″+.002; the "No Go" size would be ⅝″—.001, giving a "Tolerance" of 0.003″.

Drilling for a pipe tap (Diagram 15). The sizes of pipe taps are not exactly what the nominal sizes indicate; they are all larger in actual diameter than their sizes show.

Example.

One-inch pipe, outside diameter, equals 1.315″; inside diameter or bore 1.049″. A pipe thread taper is ¾″ per foot.

Exercise.

On a 9″ x 12″ piece of paper draw the diagrams shown as follows:—

Diagrams 4, 6, 7, 9, 13 and 15 in front sectional elevation, and diagrams 1, 2, 3, 5, 8, 10, 11, 12 and 14 in isometric, as shown. Obtain approximate sizes from the printed diagrams by using a ⅝″ to 1″ scale.

NOTATIONS FOR HEAT OPERATIONS

The various applications of heat to metal are perhaps more important than tool operations. Products may be accurately made and well finished, then their usefulness and life may be reduced by careless heat treatment. Scientific heat treatment for metals is a very interesting study, and its application is usually in the hands of experienced, dependable workmen.

Carburizing (Diagram 1). Low carbon steels may have the outer case enriched by adding carbon, which practically turns the case into tool steel. The operation of adding the carbon is called "carburizing". The work may be packed in a pot with a carburizing material such as charcoal, bone, leather, horn, or hoofs, and heated in a furnace at 1700° Fahrenheit to 1800° Fahrenheit. In six hours the carbon will penetrate 1/16″ deep. Another method is to immerse the work in a molten bath of cyanide of potassium or surface hardening powder. The pack method and the bath method prevent decarburizing and oxidizing, and give a steady, uniform heat.

Case-hardening (Diagram 2). This operation follows carburizing. The work is now treated as though it were a tool steel. It is heated from 1400° Fahrenheit to 1450° Fahrenheit, and quenched, producing a case with file hardness and a tough core. A tempering operation follows the quench in some cases. The work is now hard, with a fine grain hard case and a tough core, making it suitable for hard wearing jobs, such as wrist pins, etc.

Hardening (Diagram 3). This operation is only intended for tool steels with varying carbon content, usually ranging from 60 point carbon to 150 point carbon. (1%=100 points). Tool steel must be heated slowly and uniformly, for this reason a muffle furnace, an electric furnace, or liquid heat salt bath should be used. The hardening heat of a steel varies with its carbon content, generally a low carbon steel requires a high heat, and a high carbon steel a low heat. The temperature at which plain carbon tool steel becomes non-magnetic denotes the hardening heat, and if the steel is quenched from this temperature, it gives a fine grain structure, maximum hardness, but it is possibly full of strains and is brittle.

Tempering (Diagram 4). This operation of reheating the steel removes the brittleness, takes out the strains, and at a recommended temperature between 400° Fahrenheit and 700° Fahrenheit gives the steel the correct degree of hardness to make it ready for the kind of work it is intended to perform. Oil or salt baths are best for this operation, although modern electric furnaces have proven very efficient. The time of duration for this operation should be sufficiently long to guarantee perfect penetration of the heat into the metal.

Forging (Diagram 5). Forging heats are much higher than hardening heats, so that the metal is in a plastic condition and can readily be shaped into the required form. Hammering at too low a heat puts strains in the metal, and in the case of tool steel, may later cause cracks. Tool steel should not be overheated as it causes a coarse grain structure.

Normalize (Diagram 6). Normalizing is an operation intended to remove strains which have been put in steel by forging or cold working. Successful hardening cannot be guaranteed unless the steel is first normalized to restore its natural condition of uniformity. The steel is heated from 1475° Fahrenheit to 1650° Fahrenheit, and cooled in air.

Harden and Temper (Diagram 7). This has already been dealt with, but it is well to note that any product having thick and thin parts should be so heated that the thick part is heated first. The heat should move towards the thinner part by conduction until the whole mass has a uniform heat. This prevents irregular expansion which causes undue strains, which may crack the steel when it is quenched and in a brittle condition.

Welding (Diagram 8). One half of a welded gear blank is shown to illustrate the features of a simple welded job. Gears may be built up in this manner consisting of an outer ring, a web and a hub, to take the place of a casting.

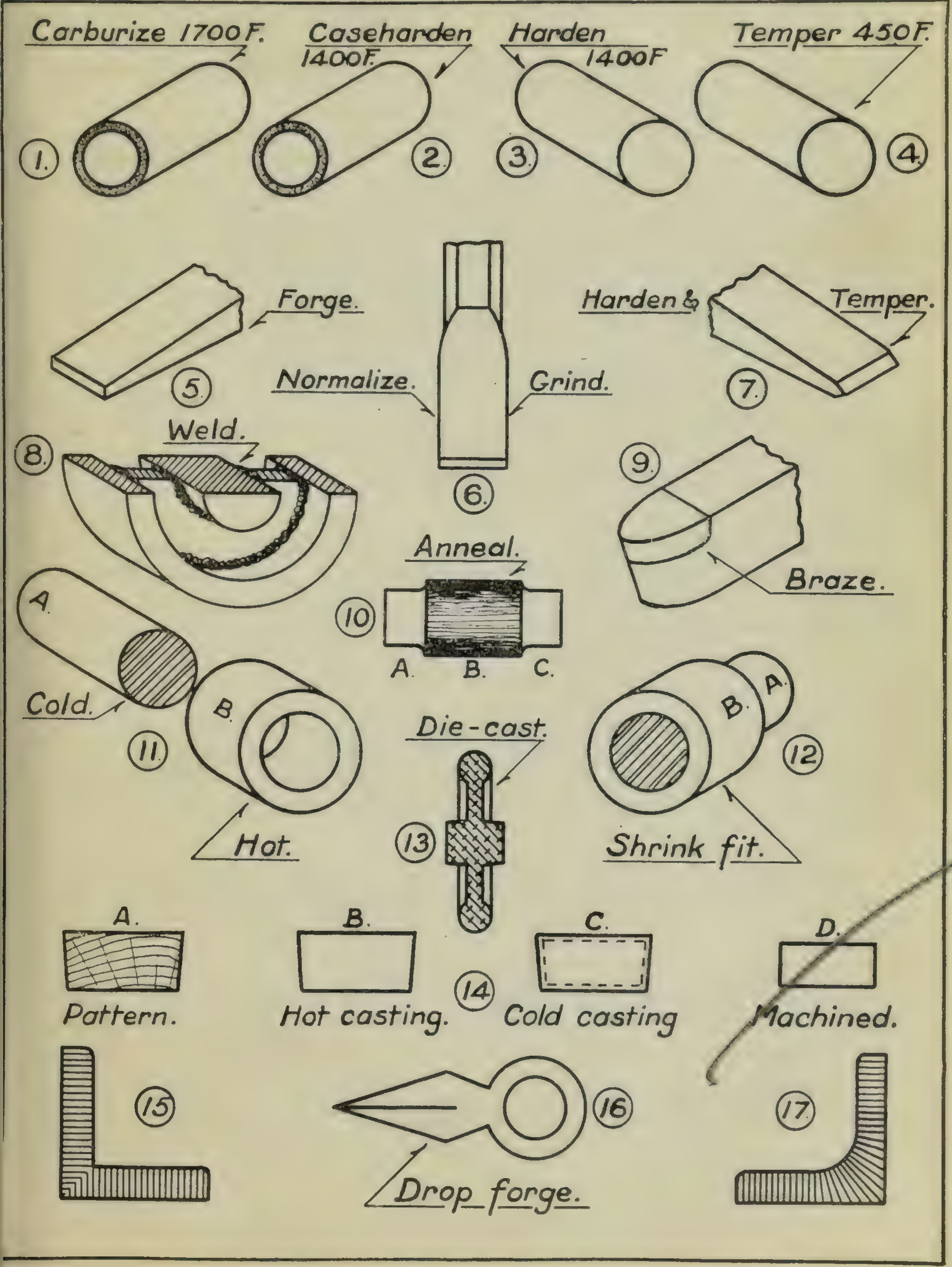
Welding has many applications in industry. The methods used are chiefly oxy-acetylene welding and electric welding.

Brazing (Diagram 9). The example shown to illustrate this operation is a tool bit, consisting of a tough, low carbon steel shank tipped with a small piece of Cemented Tungsten Carbide which is very hard and cuts at four times the speed of high speed steel.

A seat is milled on the shank to which the tip is fitted. The work is heated in a preheating furnace, then, after coating with brazing compound, a strip of brazing metal is placed between the tip and the shank, and the tool is heated to 1900° Fahrenheit to melt the brazing metal. When the tool is removed, the tip is held tightly to its seat until the metal cools. Brazing has many applications, and can be carried out with a charcoal fire or a brazing torch.

Anneal (Diagram 10) Carbon Tool Steel. Annealing is an operation intended to produce softness or to give the metal machinability. **Quick annealing** requires that the steel be heated just below the hardening heat and cooled in air until it is a black heat, when it may be quenched and used. This is very unsatisfactory for high carbon steels. Long annealing is true annealing. The work is heated slightly above the hardening heat and held there for a long period, then cooled very slowly, either by cooling with the furnace

NOTATIONS FOR HEAT OPERATIONS.



or by burying the work in ashes. The piece of tool steel in diagram 10 shows at (B) the oxidized skin of the metal which has also been decarburized, by burning out some of the carbon while in the fire or furnace. This must be removed by turning as shown at (A) and (C), so that when hardened, (A) and (C) will produce maximum hardness while (B) will not.

Shrinkage Fit (Diagrams 11 and 12). This is a method of fastening two parts together by taking advantage of the natural law of expansion and contraction of iron or steel. Parts (A) and (B), diagram 11, are to be fitted together. For shaft sizes (1″ to 2″) diameter (A) is made oversize, 0.0025″ to 0.0035″, the hole in (B) is standard size. (B) is now heated, which causes it to expand, and then it is placed on shaft (A), diagram 12. As contraction takes place it is held securely to the part (A) because of the difference between the hole diameter and the shaft diameter.

Die-casting (Diagram 13). This is a method of producing finished castings by forcing metals with low melting points into steel dies. After the metal partly cools the dies are opened and the casting removed. The castings have a nice finish, and are accurate to size.

Holes can be cast with a smooth surface and screw threads (both internal and external) can be produced in this way. Tin base metals are most suitable for die-casting and shrink very little. The zinc base metals shrink more, and if aluminum is used the castings have a very high shrinkage. The lead base metals are used for castings which are not required to withstand much wear.

Allowances for castings (Diagrams A, B. C and D — 14). A wood pattern is shown at A. Note the taper on the pattern, this is called the "draft" or "draw" to facilitate the removal of the pattern from the sand in the mold. The draft is usually $\frac{1}{8}''$ for each foot of surface to be drawn.

Shrinkage. Diagram B shows the hot metal. As this metal cools it shrinks, usually $\frac{1}{8}''$ per foot in length, but varies for different metals.

The pattern-makers' shrink rule has graduations which are longer than standard measurements. The one-tenth shrink allowance is used for cast-iron, although it is not the proper allowance for all forms of castings.

Shrinkage allowances for: Cast-iron $\frac{3}{32}''$ to $\frac{1}{8}''$ per foot; Common brass $\frac{3}{16}''$ per foot; Yellow brass $\frac{7}{32}''$ per foot; Bronze $\frac{5}{32}''$ per foot; Aluminum $\frac{7}{32}''$ to $\frac{1}{4}''$ per foot; Steel casting $\frac{3}{16}''$ per foot.

Diagram C shows the cold metal which, in the case of cast-iron, is covered with a hard skin.

Finish allowance (Diagram 14D). Allowances for machining varies considerably, but usually 1/8" is allowed for the machining operation. Large castings would be provided with a greater machining allowance.

Drop forging (Diagram 16). This operation is carried out by placing the heated material between two dies, the lower part is stationary, and the upper one drops with considerable force squeezing the plastic, red hot metal into the form of the dies. The work should be designed to allow for a "draft" varying from 3° to 10°, and a shrinkage of from 1/8" per foot to 3/16" per foot.

Filleting castings (Diagrams 15 and 17). Diagram 15 shows an angle piece which has been cast without a fillet. As the metal cools, the crystals are arranged as shown, lining up at right angles to the cooling face. This angle will readily fracture at the corner at 45°. Diagram 17 shows an angle which is filleted. The lines show how the crystals line up giving no distinct line of possible fracture. In addition to this the fillet adds more metal and therefore greater strength to an otherwise weak spot.

Extrusion of metals. This operation forces heated metal through an aperture of the shape required. In this manner a continuous bar or pipe, the shape of the cross-section of the die, can be made. The metals used for this process are lead, tin, copper, zinc, antimony, aluminum and bismuth or their alloys.

Exercise.

On a 9" x 12" piece of paper, sketch the given diagrams with the aid of compasses. Represent the notations as shown.

RIVETED JOINTS

Rivets are used to fasten metal parts together permanently. They are used extensively in assembling boilers, ships, bridges, and buildings, etc. Large rivets are heated and placed in position in holes passing through the metal plates, then while the one head already formed on one end is supported, the projecting end is hammered with a pneumatic or hydraulic tool to form the second head which presses the plates tightly together. As the heated rivet cools, contraction takes place and the rivet exerts still greater pressure on the plates. Small soft iron rivets and copper rivets are usually riveted when cold.

Forms of Rivet Heads.

Cup Head rivet (diagram 1). This is sometimes called a Snap Head rivet and is the commonest type of rivet head used.

The Steeple Head or Conical Head rivet is shown in upper diagram 2.

The Pan Head rivet is shown in lower diagram 2.

The Countersunk Head rivet is shown in upper diagram 3. This type of head is selected where it is necessary to have the surface of the plate clear to fit against some other part.

Proportions of Rivets. The proportions of rivets are expressed in terms of the diameter (D) of the body of the rivet. The length of the rivet is the distance from the under side of the manufactured head to the end of the tail, before the second head is formed. The proportions of the rivets are shown in diagrams 1, 2, and 3.

Use of Scale for Rivet Proportions. Diagram 4. To obtain proportions of a rivet use the scale as follows: The rivet in diagram 1 is ¾″ diameter. To obtain 1.7D, first divide 1.7 by 2 giving .85. Now set the dividers to the vertical measurement shown by the dotted line between 8 and 9 for ¾″ diameter, and mark this distance on each side of the centre line giving 1.7 of ¾″ diameter.

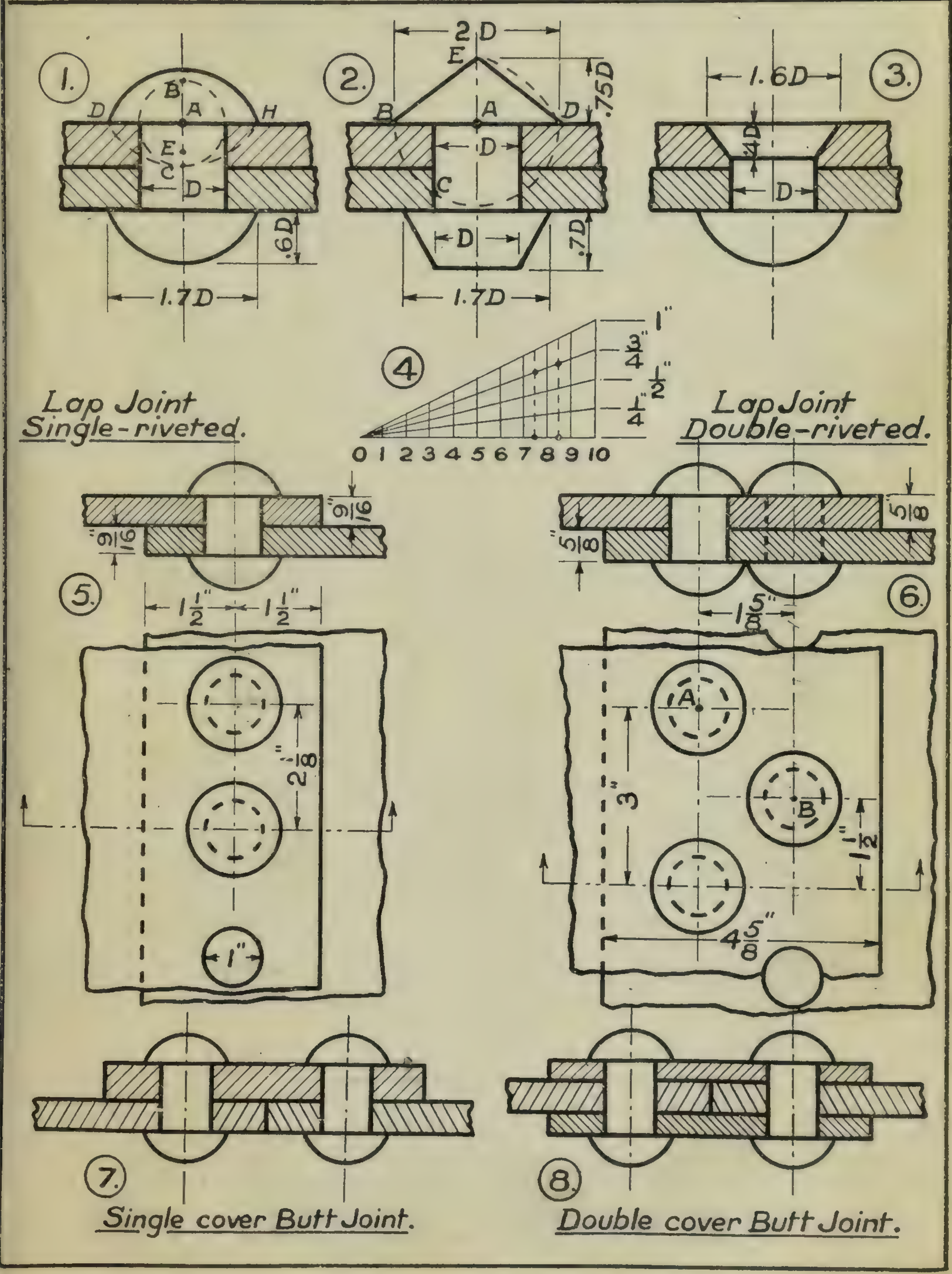
Geometrical Construction of Cup Head. Diagram 1. With centre A and radius equal ½ diameter of rivet describe a circle cutting the centre line at B and C. With B as centre and radius BC describe an arc DH. Make BE equal to AD. With E as centre and radius ED describe the arc DH.

Geometrical Construction of Steeple Head. Diagram 2. With A as centre and radius equal to diameter of rivet, describe semicircle BCD cutting rivet at C. With C as centre and radius CD describe an arc cutting centre line at E. Join BE and ED.

Lap Joint Single Riveted. Diagram 5. This is the simplest type of riveted joint to fasten two plates together.

Lap Joint Double Riveted. Diagram 6. This joint has two rows of rivets. The pitch of the rivets is the same in both rows. When a riveted joint has two or more rows of rivets they are usually arranged zig-zag as shown here in diagram 6.

RIVETED JOINTS.



Lap Joint Single-riveted.

Lap Joint Double-riveted.

Single cover Butt Joint.

Double cover Butt Joint.

Single Cover Butt Joint. Diagram 7. The square edges of the plates butt together as shown and one cover plate or strap is used to hold them together. The surface of the plates is continuous on one side. The cover strap thickness is usually 1¼ times the thickness of the plates.

Double Cover Butt Joint. Diagram 8. This is a much stronger joint than the single cover butt joint and the thickness of the cover plates are made less than the thickness of the plates being connected.

The Pitch of the Rivets is the distance from the centre of one rivet to the centre of the next rivet in the same row. The distance from the edge of the plate to the centre line of the nearest row of rivets is 1½ times the diameter of the rivets as in diagram 5.

Pitch Between Rows of Rivets or back pitch is the distance between the centre line of rivets measured at right angles to the centre line. Diagram 6 shows the pitch between rows of rivets 1-5/8″.

Diagonal Pitch is the distance between the centre of two rivets in adjacent rows of a zig-zag joint as in diagram 6 from A to B.

Note. A single riveted joint is approximately 60 per cent. the strength of the solid plate and a double riveted joint 75 per cent. For boilers the plates are usually bevelled at 80° instead of being cut at 90° as shown in these diagrams.

Exercise. On a 9″x12″ sheet of drawing paper duplicate these diagrams. In diagrams 1, 2, and 3, plates are ⅜″ thick and rivets ¾″ diameter. Draw diagrams 5 and 6, scale half full size. Diagram 7, plate ½″ thick, cover plate ⅝″ thick, rivets ⅞″ diameter, pitch 2¾″, scale half full size. Diagram 8, plates 9/16″ thick, cover plates ⅜″ thick, pitch 2¾″, rivets ⅞″ diameter. Scale, half full size.

NOTE—Diagrams 5 and 6 are drawn by 1st angle projection. You are required to draw them by 3rd angle projection.

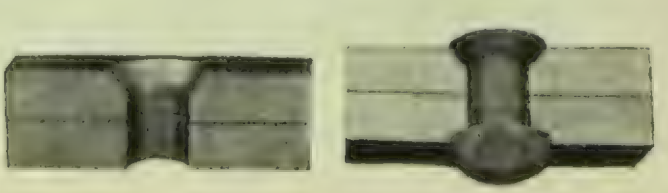


TABLE OF DECIMAL EQUIVALENTS

Of 8ths, 16ths, 32nds and 64ths of an inch

8ths.

$\frac{1}{8}=.125$
$\frac{1}{4}=.250$
$\frac{3}{8}=.375$
$\frac{1}{2}=.500$
$\frac{5}{8}=.625$
$\frac{3}{4}=.750$
$\frac{7}{8}=.875$

16ths

$\frac{1}{16}=.0625$
$\frac{3}{16}=.1875$
$\frac{5}{16}=.3125$
$\frac{7}{16}=.4375$
$\frac{9}{16}=.5625$
$\frac{11}{16}=.6875$
$\frac{13}{16}=.8125$
$\frac{15}{16}=.9375$

32nds.

$\frac{1}{32}=.03125$
$\frac{3}{32}=.09375$
$\frac{5}{32}=.15625$
$\frac{7}{32}=.21875$
$\frac{9}{32}=.28125$
$\frac{11}{32}=.34375$
$\frac{13}{32}=.40625$
$\frac{15}{32}=.46875$
$\frac{17}{32}=.53125$
$\frac{19}{32}=.59375$
$\frac{21}{32}=.65625$
$\frac{23}{32}=.71875$
$\frac{25}{32}=.78125$
$\frac{27}{32}=.84375$
$\frac{29}{32}=.90625$
$\frac{31}{32}=.96875$

64ths.

$\frac{1}{64}=.015625$
$\frac{3}{64}=.046875$
$\frac{5}{64}=.078125$
$\frac{7}{64}=.109375$
$\frac{9}{64}=.140625$
$\frac{11}{64}=.171875$
$\frac{13}{64}=.203125$
$\frac{15}{64}=.234375$
$\frac{17}{64}=.265625$
$\frac{19}{64}=.296875$
$\frac{21}{64}=.328125$
$\frac{23}{64}=.359375$
$\frac{25}{64}=.390625$
$\frac{27}{64}=.421875$
$\frac{29}{64}=.453125$
$\frac{31}{64}=.484375$
$\frac{33}{64}=.515625$
$\frac{35}{64}=.546875$
$\frac{37}{64}=.578125$
$\frac{39}{64}=.609375$
$\frac{41}{64}=.640625$
$\frac{43}{64}=.671875$
$\frac{45}{64}=.703125$
$\frac{47}{64}=.734375$
$\frac{49}{64}=.765625$
$\frac{51}{64}=.796875$
$\frac{53}{64}=.828125$
$\frac{55}{64}=.859375$
$\frac{57}{64}=.890625$
$\frac{59}{64}=.921875$
$\frac{61}{64}=.953125$
$\frac{63}{64}=.984375$

FINISH MARKS, NOTATION AND TITLE

It is impossible to give a workman sufficient information about an article to be made by use of lines and figures alone. Finish marks, notations and title, are used to make the drawing a complete information sheet, so that no chance of error may be possible in producing the article exactly as it was intended to be produced.

Diagram 1. F — "Finish this side," shown in photograph A. This means that the side is to be finished, such as filed, ground, planed or milled, but if any special finish is required, it is usual to state what finish is necessary.

Diagram 2. f.a.o — "Finish all over". This means that all sides must be machined to whatever sizes are put on the drawing. If any particular limits of accuracy are required they are usually shown by special limit dimensions, otherwise it is understood that measurements will be made by "caliper feel", or sight reading from a scale rule.

Diagram 3. Tap ¼″ — 20 U.S.S. — R.H. This is an abbreviation for Tap ¼″ — 20 threads, United States Standard — Right-Hand. If (R.H.) is not included in the notation, it is understood that threads are right-hand, unless specified (L.H.) left-hand. The workman is expected to find the suitable tap drill size from a table on page 73.

Diagram 4. Two views are shown of a part to be drilled and reamed. If a hole is less than 1″ diameter, it is drilled 1/64″ less than the nominal size to allow for reaming, because a drill does not make a hole exactly round or exact to size, but a reamer ,does. (See photograph D.)

Diagram 5. This drawing shows two views of an object with clearances on the sides and one end. A finish mark "f" only indicates a finish on an uninterrupted side. If the sides have a clearance as shown, all parts of the sides to be finished must be indicated by the "f" mark. (See photograph B.)

Diagram 6. Drill ¾″, bore 13/16″, thread ⅞″—16 U.S.F.—R.H. This collar is drilled ¾″ (to make room for boring bar) ; bored 13/16″ (to make hole concentric, as drills usually drill slightly off centre). Threaded in the lathe ⅞″ diameter, 16 threads per inch, United States Standard Form. (This means the thread is United States Standard Shape, but does not have the standard number of threads per inch.) Right-hand.

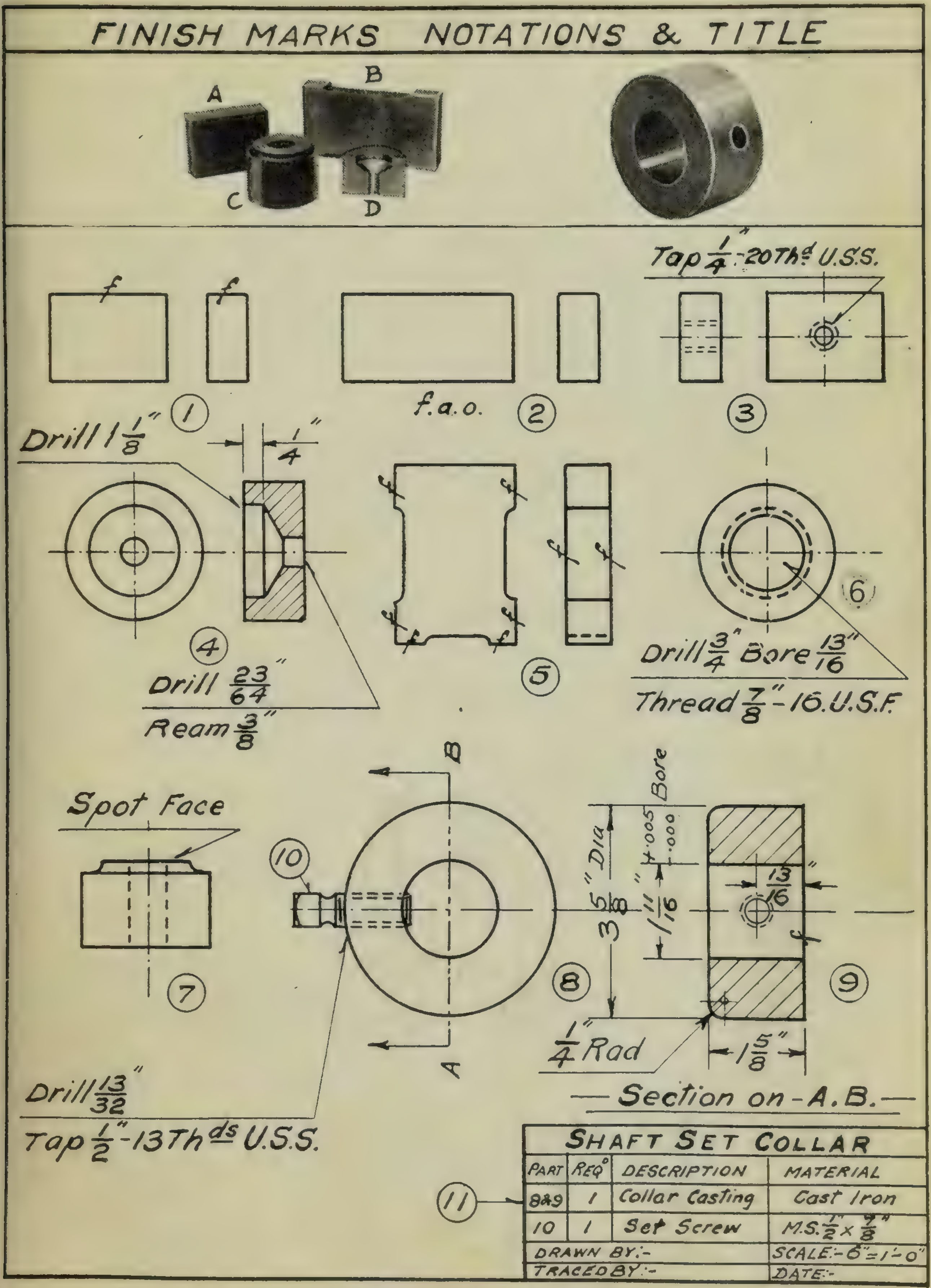

FINISH MARKS NOTATIONS & TITLE
A
B
C
D
f
f
1
f.a.o.
2
Tap 1/4"-20Th.d U.S.S.
3
Drill 1 1/8"
1/4"
4
Drill 23/64"
Ream 3/8"
f
5
6
Drill 3/4" Bore 13/16"
Thread 7/8"-16.U.S.F.
B
Spot Face
7
10
8
A
3 5/8" Dia
Bore
1 11/16" +.005 .000
13/16"
f
9
1/4" Rad
1 5/8"
Drill 13/32"
Tap 1/2"-13Th.ds U.S.S.
Section on - A.B.
SHAFT SET COLLAR
PART | REQ.D | DESCRIPTION | MATERIAL
8&9 | 1 | Collar Casting | Cast Iron
10 | 1 | Set Screw | M.S. 1/2" x 5/8"
DRAWN BY:-
SCALE:- 6"=1'-0"
TRACED BY:-
DATE:-
11

Diagram 7. "Spot face boss". This operation is usually done in a drill press with a spot facing tool, to provide a machined face at right angles to the axis of the hole for some other part to work against evenly, as shown in photograph C.

Diagrams 8 and 9. A simple assembly drawing showing the use of reference numbers to give the location and function of parts which are shown dimensioned, and are listed in the title diagram 11. (See Set Screws in lesson on Screwed Fastenings.)

Diagram 11. A "Title" such as the one illustrated is designed especially for shop requirements, and should always be placed in the bottom right-hand corner of a working drawing. The size of it will depend entirely upon what details it will be required to contain. The actual title or name of the drawing will be in capital letters not larger than ⅛″ to 3/16″ high. All other printing to be in lower case 1/16″ to 3/32″ high.

Column one shows the part number.
Column two shows the number of parts required.
Column three shows the name of the part.
Column four shows the material that the part is made from.

Exercise: On a 9″x12″ piece of drawing paper duplicate the lesson diagrams and arrange them a suitable size to fit the paper.

IRON AND STEEL DEFINITIONS

At the Brussels Congress of the International Association for Testing Materials held in 1906, the following definitions of the most important forms of iron and steel were adopted:

Alloy Cast Irons—Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy Steels—Steels which owe their properties chiefly to the presence of an element other than carbon.

Basic Pig Iron—Pig iron, containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process (restricted to pig iron containing not more than one per cent. of silicon).

Bessemer Pig Iron—Iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent. of phosphorus).

Bessemer Steel—Steel made by the Bessemer process, irrespective of carbon content.

Blister Steel—Steel made by carbonizing wrought iron by heating it in contact with carbonaceous matter.

Cast Iron—Iron containing so much carbon or its equivalent that it is not malleable at any temperature. It is recommended drawing the line between cast iron and steel at 2.20 per cent. carbon.

Cast Steel—The same as crucible steel; obsolete and confusing.

Charcoal Hearth Cast Iron—Cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

Converted Steel—The same as blister steel.

Crucible Steel—Steel made by the crucible process, irrespective of carbon content.

Gray Pig Iron and Gray Cast Iron—Pig iron and cast iron in the fracture of which the iron itself is nearly concealed by graphite, so that the fracture has the gray color of graphite.

Malleable Castings—Castings made from iron which when first made is in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Malleable Pig Iron—An American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without re-melting.

Open-Hearth Steel—Steel made by the open-hearth process irrespective of carbon content.

Pig Iron—Cast iron which has been cast into pigs direct from the blast furnace.

Puddled Iron—Wrought iron made by the puddling process.

Puddled Steel—Steel made by the puddling process, and necessarily slag-bearing.

Refined Cast Iron—Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Shear Steel—Steel usually in the form of bars, made from blister steel by shearing it into short lengths, piling and welding these by rolling or hammering them at a welding heat. If this process of shearing, etc., is repeated, the product is called "double-shear steel."

Steel—Iron which is malleable at least in some one range of temperature, and in addition, is either (a) cast into an initially malleable mass or, (b) is capable of hardening.

Steel Castings — Unforged and unrolled castings made of Bessemer, open-hearth crucible or any other steel.

Washed Metal—Cast iron from which most of the silicon and phosphor have been removed by the Bell-Krupp process without removing much of the carbon; still contains enough carbon to be cast iron.

Weld Iron—The same as wrought iron; obsolete and needless.

White Pig Iron and White Cast Iron—Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron — Slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

SKETCHES OF RIVETED WORK

You are already familiar with some of the various riveted joints and the types of rivets used to fasten plates together. You have also sketched the important rolled structural shapes used in riveted work. This lesson will illustrate a few of the simple constructional forms which may be obtained by riveting parts together.

Use of Angle Bar. Angle bar or angle iron is made in various sizes and has a wide use. It is shown here in diagrams 1, 5 and 8, used for fastening parts together at right angles. Angles may be obtained with equal or unequal legs. Diagram 1 shows an angle bar used to fasten two plates at right angles to each other. Each plate is fastened to the angle bar with a single row of rivets. One rivet is in section and one rivet shown by dotted lines, indicating that the rivets are "staggered" in relation to each other.

Use of Tee-iron (Diagram 2). The tee-iron is shown connecting two plates together in a butt joint which makes a stiff, strong joint. The tee forms a backbone to the otherwise weak joint. Compare this with a single strap butt joint in the lesson on rivet joints.

A Flanged Plate Joint (Diagram 3). Here is an example of two plates fastened together at right angles by bending over one plate at right angles, forming a flange and then riveting the other plate to it.

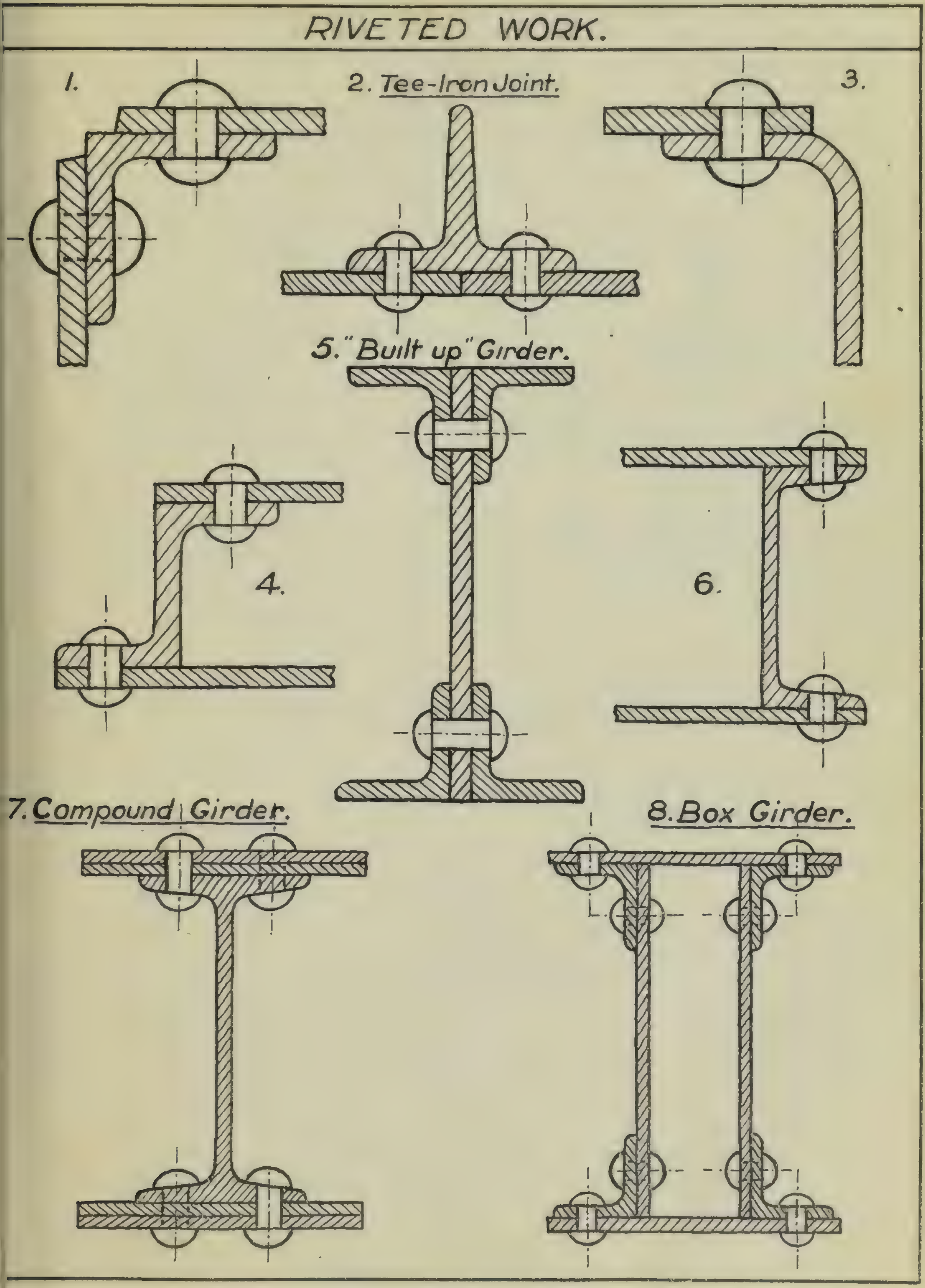
Joints to Connect Parallel Plates. These are shown in diagram 4, using a double-angle or Z-iron bar, and in diagram 6 using a channel of the required size.

Building up a Simple Girder (Diagram 5). Four angle bars are riveted to a plate to make a simple girder. A single row of rivets is used in each connection.

Building a Compound Girder (Diagram 7). A rolled steel bar of I-beam section is used and two plates are riveted to each flange with staggered rivets as shown. The flanges of the I-beam are strengthened by the addition of the plates, the web of the bar being stronger than the flanges without the additional plates.

Building a Box Girder. This hollow girder is built up of four angle bars and four plates of a suitable size. The angles are connected to the plates with a single row of rivets which are "staggered."

Exercise: On a 9"x12" piece of paper, sketch freehand the given examples of riveted work. Space your work and approximate the sizes, or measure the printed diagrams with a scale of ⅝" to 1" to find the sizes exactly.



Freehand Sketches

EXAMINATION QUESTIONS

Test. Sketching Simple Objects.

You are given freehand sketches of some simple objects. You are required to sketch freehand the objects as stated below.

(A) Steeple head rivet set and button head rivet set are shown in diagrams 1 and 3. Sketch the left of the centre line as a sectional elevation and the right half of the centre line in elevation.

(B) Sketch the punch, diagram 2, in elevation as shown and the die, diagram 4, in sectional elevation.

(C) Sketch the Gib Key as shown in diagram 5, and finish the two end elevations.

(D) Sketch the plan of the Jack Cap as shown in diagram 6, and make a sectional elevation when cut on section line AB.

(E) Sketch the elevation of the valve shown in section in diagram 7.

(F) Sketch the plan of the Grinder Flange, diagram 8, and make a sectional elevation when cut on the section line AB.

Note: Use a compass for all circles, but finish the sketches freehand.

---

(1) Make a list of the various angles that can be obtained by use of 60° and 45° set squares.

(2) How many parts can a circle be divided into by use of 60° and 45° set squares used with a tee square?

(3) Name 5 methods of representing an object and state the advantages or disadvantages of each.

(4) Name the sectional shapes of bars or rods that can be obtained made of Carbon Tool Steel.

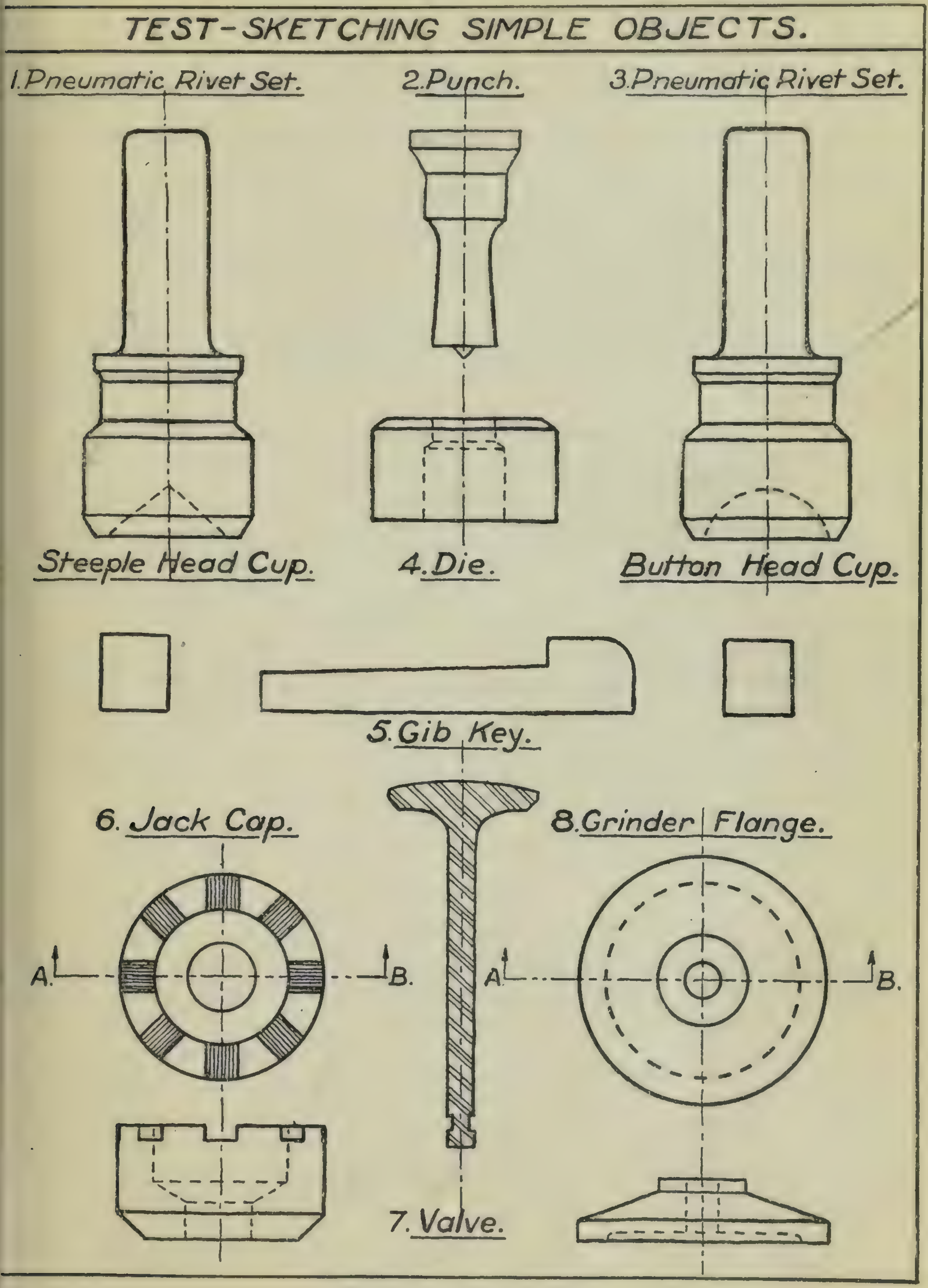
(5) Name the sectional shapes of bars or rods that can be obtained made of cold rolled machine steel.

(6) Name the sectional shapes of bars or rods that can be obtained made of mild steel. Include also structural steel rolled forms.

(7) Name some of the features of a cold rolled metal as compared to hot rolled metal if both are made of mild steel.

(8) Show methods of representing breaks in 6 forms of rolled metal bars or rods.

(9) What do you understand by "representative fraction of a scale?" Illustrate your answer with the following scales 1¼″ to 1′-0″, 2″ to 1′-0″, 4″ to 1′-0″.



Freehand Sketches

(10) How much would 6½″ full size measure with ⅝″ to 1″ scale?

(11) What advantage has a diagonal scale over a plain scale?

(12) Illustrate what is meant by (a) A Reduced Scale. (b) An Enlarged Scale.

(13) Compare "First" and "Third" Angle Projection.

(14) Illustrate and name 8 different types of lines used in Engineering Drawing.

(15) Illustrate the following—(a) A small and large dimension. (b) A small and large angle. (c) A small and large radius. (d) The diameter of a small and large hole. (e) A tapped hole for a ½″-13 U.S.S. screw.

(16) Make an Isometric sketch of a small vee block.

(17) Make an Oblique sketch of a small tee slotted block.

(18) Sketch a round head and countersunk head rivet joint as follows—(a) A half sectional elevation. (b) A sectional elevation.

(19) Illustrate the section lines used to show the following materials on rectangles 1″x2″—Cast iron, wrought iron, cast steel, alloy steel, babbitt, copper or brass, aluminum, rubber or vulcanite, wood-end and side grain.

(20) Sketch the following rivet joints in section, for 1″ diameter rivet—(a) A rivet with 2 cup heads. (b) A rivet with a steeple head and pan head. (c) A rivet with countersunk and cup head. Show the proportions of each.

(21) Draw a scale suitable for use in obtaining the proportions of a rivet.

(22) Draw the geometric construction of a Cup head rivet.

(23) Sketch the following rivet joints—(a) A single riveted lap joint. (b) A double riveted lap joint. (c) A single cover butt joint. (d) A double cover butt joint.

(24) What do you understand by the following terms?—(a) The "pitch" of rivets. (b) "Pitch" between rows of rivets. (c) "Diagonal pitch" of rivets. (d) Zig-zag riveting.

(25) Illustrate a "title" as used on a drawing of a shaft set-collar.

(26) Sketch built-up work to show the use of the following rolled forms—(a) Angle iron. (b) Tee iron. (c) Double angle iron. (d) Channel iron. (e) I-beam.

STAGES OF CIRCULAR DRAWING

The adjoining diagram sheet shows a simple wheel used for turning a valve which you will probably find on some of the plumbing fixtures in your own home. If you can find a wheel it would be advisable to have it before you while you are studying this lesson and making your own drawing.

A Freehand Sketch of the Wheel. It is shown in the top left-hand corner of the diagram sheet, giving the form and dimensions of the wheel. One half is shown in section to give a clear idea of its shape and form. The bevel on the top boss is 45° and 1/32″ measured parallel with the axis of the wheel.

Stage 1. Spacing the Required Drawing. Diagram 1 shows the plan and sectional elevation outline spaced centrally and uniformly. The first lines put on the drawing are the centre lines, then the circle is drawn. From the circle projectors are drawn to obtain the width of the sectional elevation.

Stage 2. Dividing a Circle into 6 equal parts. This is obtained by using the 60° set square with the tee square. The lines are drawn passing through the centre of the circle of 360° giving 60° divisions. Another method would be to step off the radius of the circle 6 times with a pair of dividers, then join the points on the circle so located. The hub circles are next drawn, then projected to the sectional elevation below. With the bow pencil compass draw the rim section circles.

Stage 3. From the rim circles project up to the plan and draw the inner rim circle. Draw the web of the wheel 3/32″ thick on sectional elevation. Draw the centre line of holes on the plan 1⅛″ diameter. Where the centre lines intersect the 60° radial lines, draw the circle for the holes ⅜″ diameter. From the holes in plan, project to the sectional elevation and mark the location of the holes in the web of the wheel.

Stage 4. Drawing Fillets. Measure ⅛″ from the web and ⅛″ from the boss and draw parallel lines to web and boss. Where these lines intersect will be the centre for the fillet radius. Set the bow compass to ⅛″ and draw the fillets touching, but not cutting the lines as shown. Draw the plan of the square hole and finish the sectional elevation.

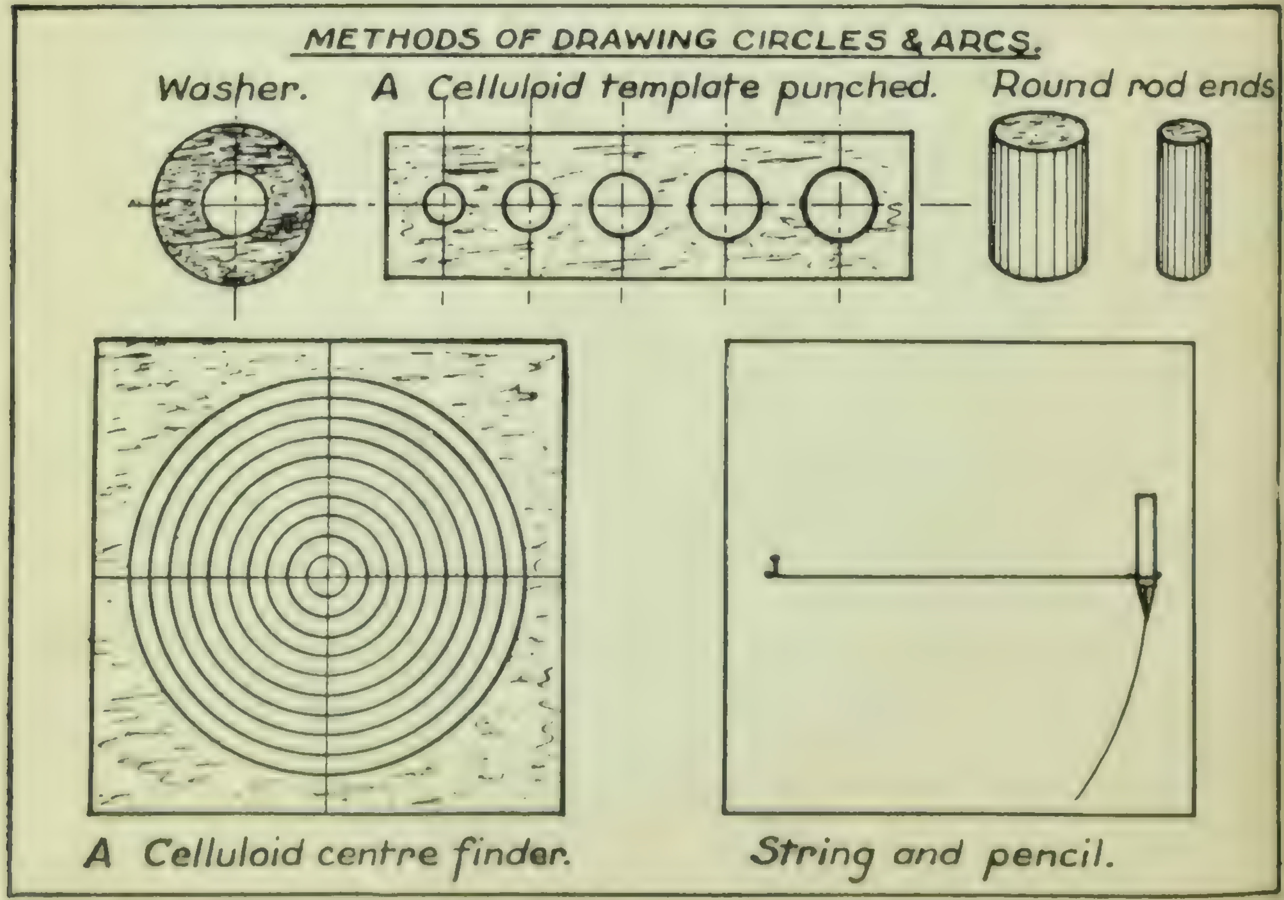
The Construction of the Drawing is now complete. Check carefully, then erase all lines not to appear on the finished pencil drawing.

Stage 5. Line in the Drawing. Use a bold, clear outline and put in section lines for brass at a 45° angle. Put in a correct centre line for the vertical centre line and a section cutting plane line for the horizontal centre line.

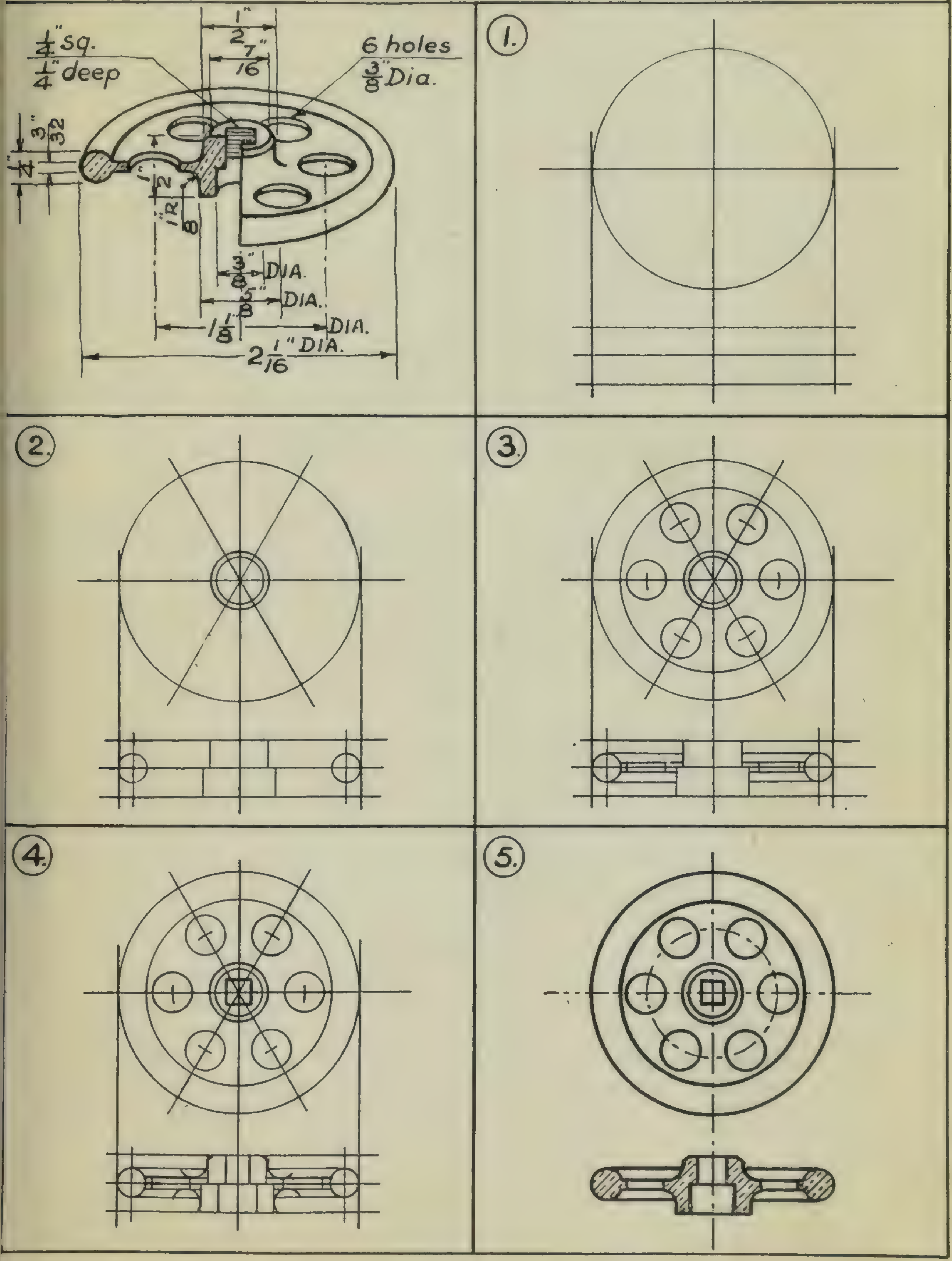
Stage 6. Put in Projectors, Dimension Lines, Notations and Figures. This stage is not shown on the diagram sheet because the student is asked to do this by himself, as explained in a previous lesson on "Lines and Figures."

Exercise: On a 9″x12″ piece of drawing paper, draw the given wheel shown in the freehand sketch. Draw the plan and sectional elevation only, with dimensions and notations.

Scale: Twice full size.


METHODS OF DRAWING CIRCLES & ARCS.
Washer.
A Celluloid template punched.
Round rod ends
A Celluloid centre finder.
String and pencil.

STAGES OF CIRCULAR DRAWING.



STAGES OF DRAWING WITH ARCS

It is frequently necessary to draw objects which are cast, and these objects usually have rounded corners and fillets. The various problems likely to be met with are shown as individual examples in diagram 1 at A, B, C, D, E, F, G. To give you an opportunity of applying some of the examples, a drawing of a wrench is provided. It is drawn in stages showing how it is designed.

Use of a Fillet Finder. (Page 58). A piece of celluloid about 4″ square may be made into a very useful fillet finder in the following manner: Draw a series of concentric circles with your dividers, scratching circles on the celluloid 1/16″ apart, with a small pin hole at the centre of the concentric circles. Place the fillet finder over the arcs on a drawing or blueprint, and when a circle coincides with an arc, prick through to locate the centre of the arc. This saves a lot of time when tracing where the centres of arcs are not visible.

Construction of Arcs. The various examples are shown in diagrams at (1) with heavy lines at A, B, C, D, E, F, G. Above each example are shown two stages of construction. It is just as though a cylinder were pushed into each corner to make a fillet form without being cut.

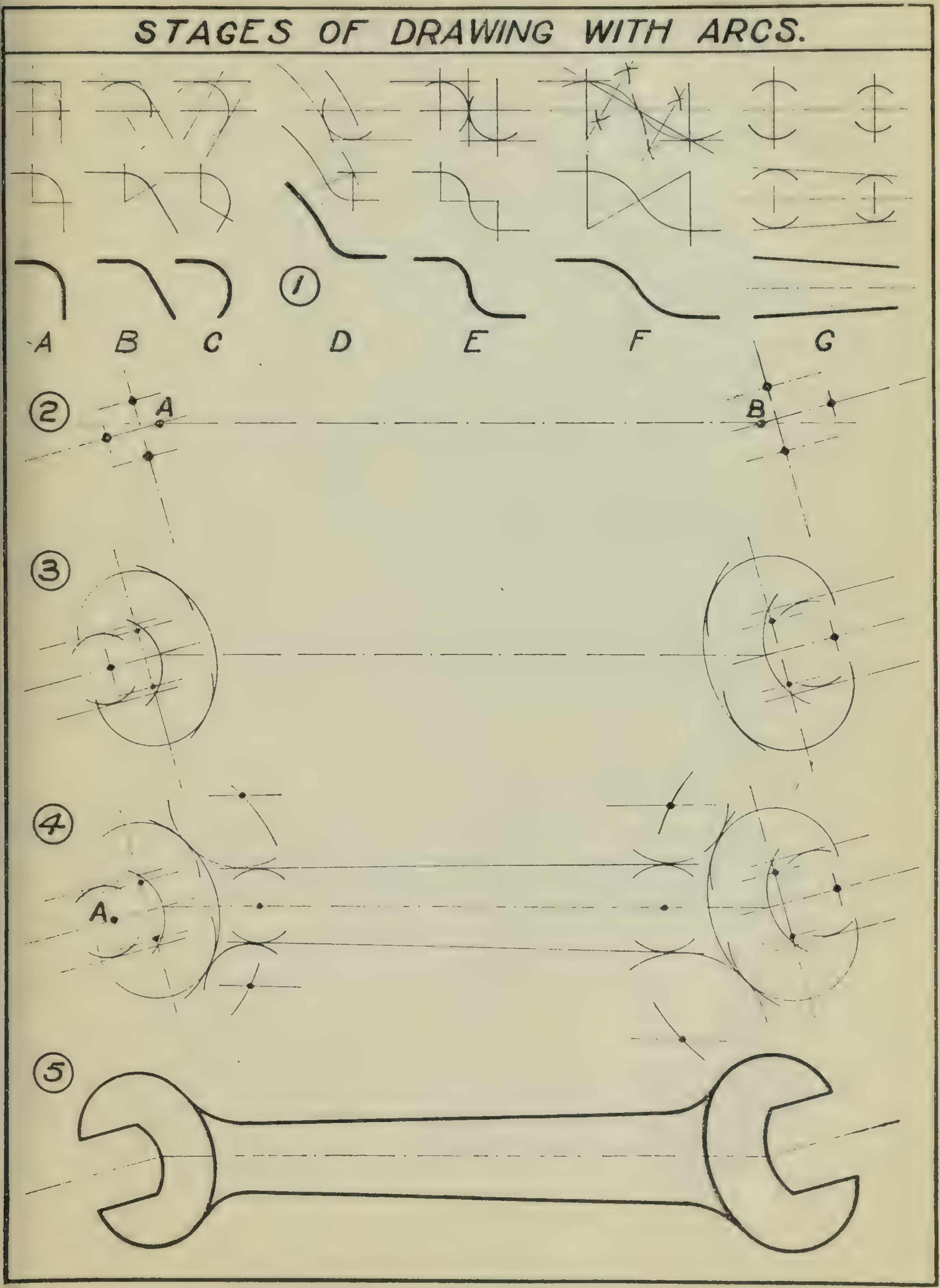
Example A. Two lines at right angles are to be rounded (convex corner) or filleted (concave corner). From the right angle corner, mark lines parallel and equidistant from the outer lines, a distance equal to the radius of the arc. From the point of intersection set the compass and describe an arc, as shown at upper diagram A. Erase lines not wanted, as shown in diagram A. For inking-in, always draw the arc first and then draw the straight lines to meet the arc. A similar method is required for the obtuse angle B and the acute angle C.

Filleting a Circle Meeting a Straight Line. This example is shown at D, diagram 1. To find the centre of the fillet, draw a line parallel with the straight line a distance from it equal to the radius of the fillet. With the compass at the centre of the circle increase the radius of the circle by the radius of the fillet required and draw an arc intersecting the straight line as shown, giving the centre of the fillet. Draw the fillet touching the circle and straight line.

Parallel Lines Connected with Arcs. These are shown at E, connected with quadrants and at F, connected with two arcs. The diagram at F shows a straight line forming chords for both arcs. The chords are bisected at right angles to locate the line which passes through the centre of the circle, part of which forms the arc.

To Lay Out Two Lines to Form a Given Taper. (Diagram 1 G). The centre distance of two circles is marked off on a centre line and two circles of given diameter are drawn about the centres. Two lines are then drawn at a tangent to the circles to give the taper required.

How to Draw a Wrench. The oblique dimension drawing provided gives all the necessary details to allow one to make a drawing which will give a practical application of the use of arcs and fillets.



STAGES OF DRAWING WITH ARCS.

Stage 1 is shown in diagram 2. Draw the centre line and mark off the length shown, 5¼″. From the two points so obtained, draw lines at 15° as shown by using the 45° and 30° set squares together on the tee square. Mark 7/16″ at one end and ⅝″ at the other end along the inclined lines to obtain the centres of the arcs to be drawn later. Measure 5/32″ from A and ⅛″ from B along the inclined lines to locate the centre lines of arcs which are drawn at right angles to the inclined lines at 15° from the vertical. Mark the centres of the arcs ½″ apart on one end, and 9/16″ apart on the other end on the lines 15° from the vertical as shown. The 3 heavy dots on each end are the centres of the various arcs required.

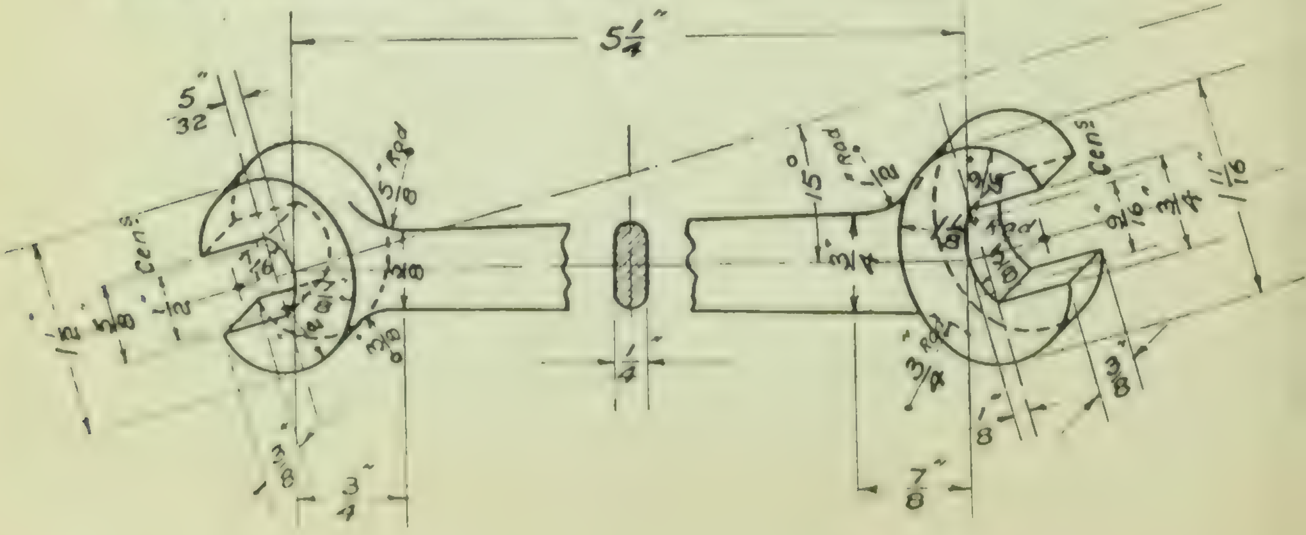
Stage 2, Diagram 3. Draw the arcs forming the heads of the wrench from the radii provided in the dimensioned drawing. Mark the width of the openings ⅝″ at one end and ¾″ at the other, by drawing lines parallel with the inclined centre lines shown.

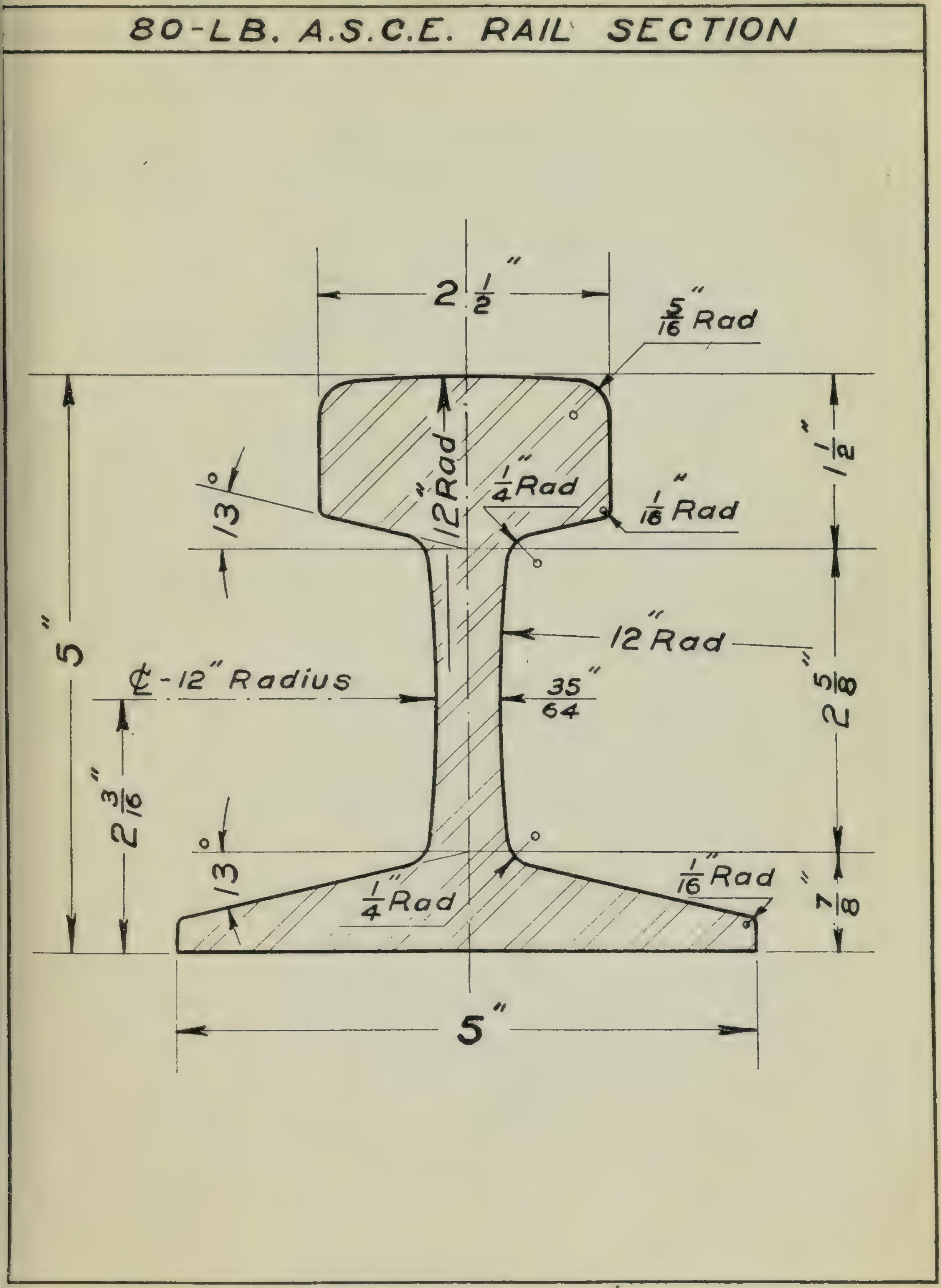
Stage 3, Diagram 4. Draw the tapered shank of the wrench. From the main centre line 5¼″ long, mark inwards ¾″ at one end and ⅞″ at the other end. From these points describe two circles ⅝″ diameter at the small end and ¾″ diameter at the large end. Draw straight lines at a tangent to these circles to form the shank.

To Draw the Fillets. The same method is used at both ends. At the small end on the upper side draw a parallel line to the edge ⅝″ from it, and a parallel line to the edge ⅜″ from the lower side. With centre (A) and a radius ⅞″+⅝″ (1½″) describe an arc on the upper side, intersecting the upper parallel line, giving the centre of the fillet. Draw the fillet ⅝″ radius. With centre (A) and a radius ⅞″+⅜″ (1¼″) describe an arc on the lower side, intersecting the lower parallel line, giving the centre of the lower fillet, draw the fillet ⅜″ radius.

Stage 4, Diagram 5. Erase all construction lines and line in the drawing with a bold line.

Exercise: Draw (scale full size) the plan of the given dimensioned wrench on a 9″ x 12″ piece of paper. Show the drawing in 5 stages, as in diagrams 2, 3, 4, 5, and add the 5th stage showing all dimensions. Arrange your drawings to give suitable spaces as required. Do not duplicate the letter diagrams A to G, as these are given for reference only.





Tracing Exercise. Test 1.

STAGES OF DRAWING WITH ARCS (TRACING)

Stages of Tracing.

A lathe dog is presented in various stages to illustrate how a simple tracing should be made. This example presents circles, arcs, straight lines and hidden lines. If the student can trace this successfully, little difficulty will be encountered in making a complete working drawing with notations, dimensions and other details.

Methods of Tracing a Drawing.

1. Tracing with a pencil on tracing paper.
2. Tracing with india ink on tracing paper.
3. Tracing with india ink on tracing cloth.

In this lesson we assume that the third method is being used.

Use of Tracing Cloth.

The tracing may be made on the dull side or the glossy side. The student is advised to use the dull side. First mount the cloth over the required drawing, see that it is stretched tightly and apply a small quantity of prepared "Pounce," which can be purchased for the purpose of cleaning the cloth of grease. Powdered chalk may be used if "Pounce" is not available. Scrape a chalk stick with a pocket knife and rub the tracing cloth all over with a piece of clean, white linen. Wipe off all traces of the powder and the cloth is ready to receive the ink.

Diagram 1 represents the drawing as it is seen through the tracing cloth which covers it.

Diagram 2 shows that all centres of arcs and circles have been located by use of the celluloid centre finder or the compasses. The small circle around the actual centre helps the tracer to quickly find the centre.

Diagram 3 shows the termination of each arc, this is an important feature to prevent running beyond the limits of the lines to be traced and thus preventing poor joints in the lines.

Note—Stages 2 and 3 show the preparations made on the drawing or blueprint before the tracing cloth is placed over it.

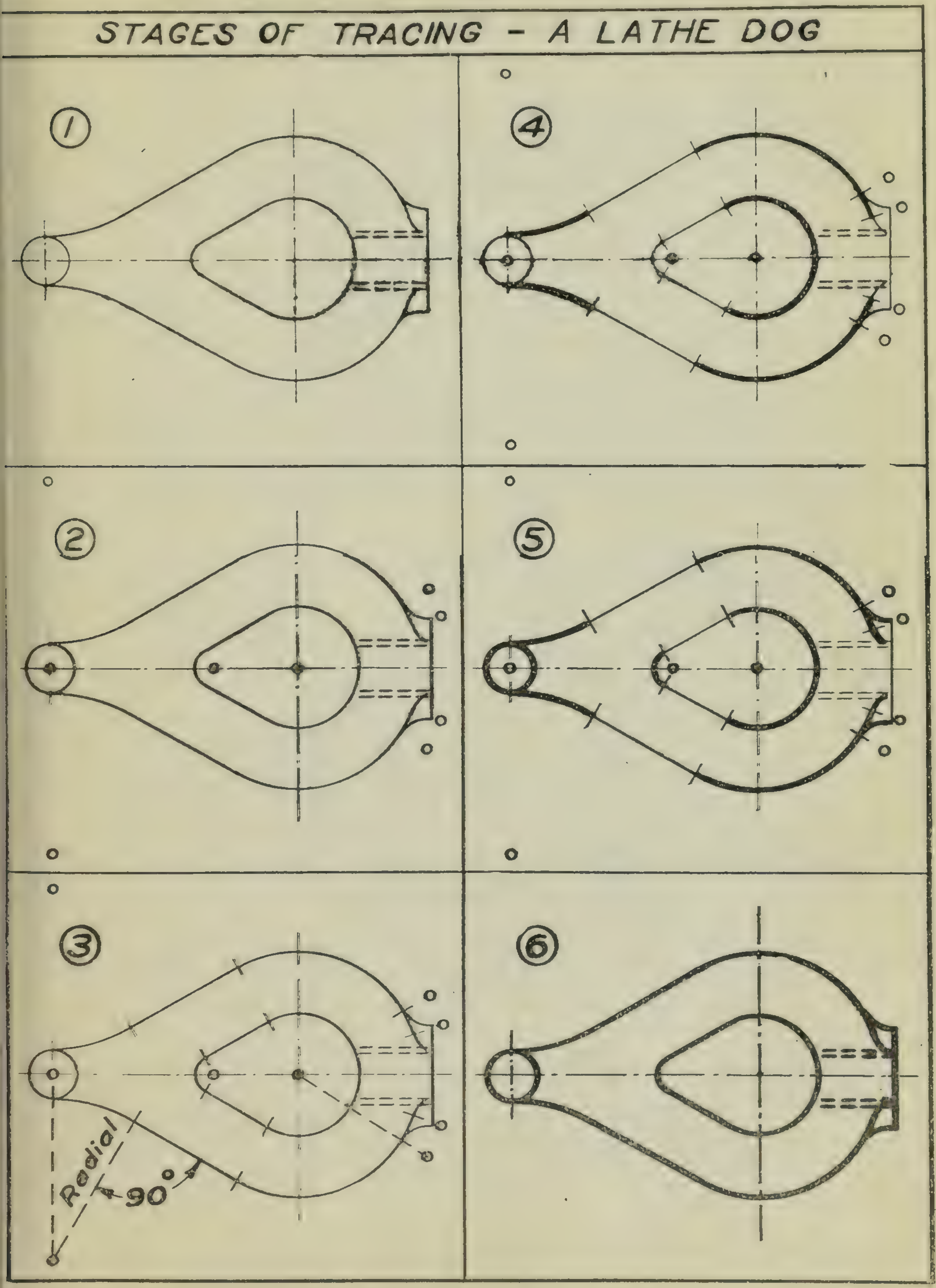
Diagram 4 shows the large arcs or circles inked in. The pens should be set to produce a line 1/32″ thick.

Diagram 5 shows the small arcs or circles inked in.

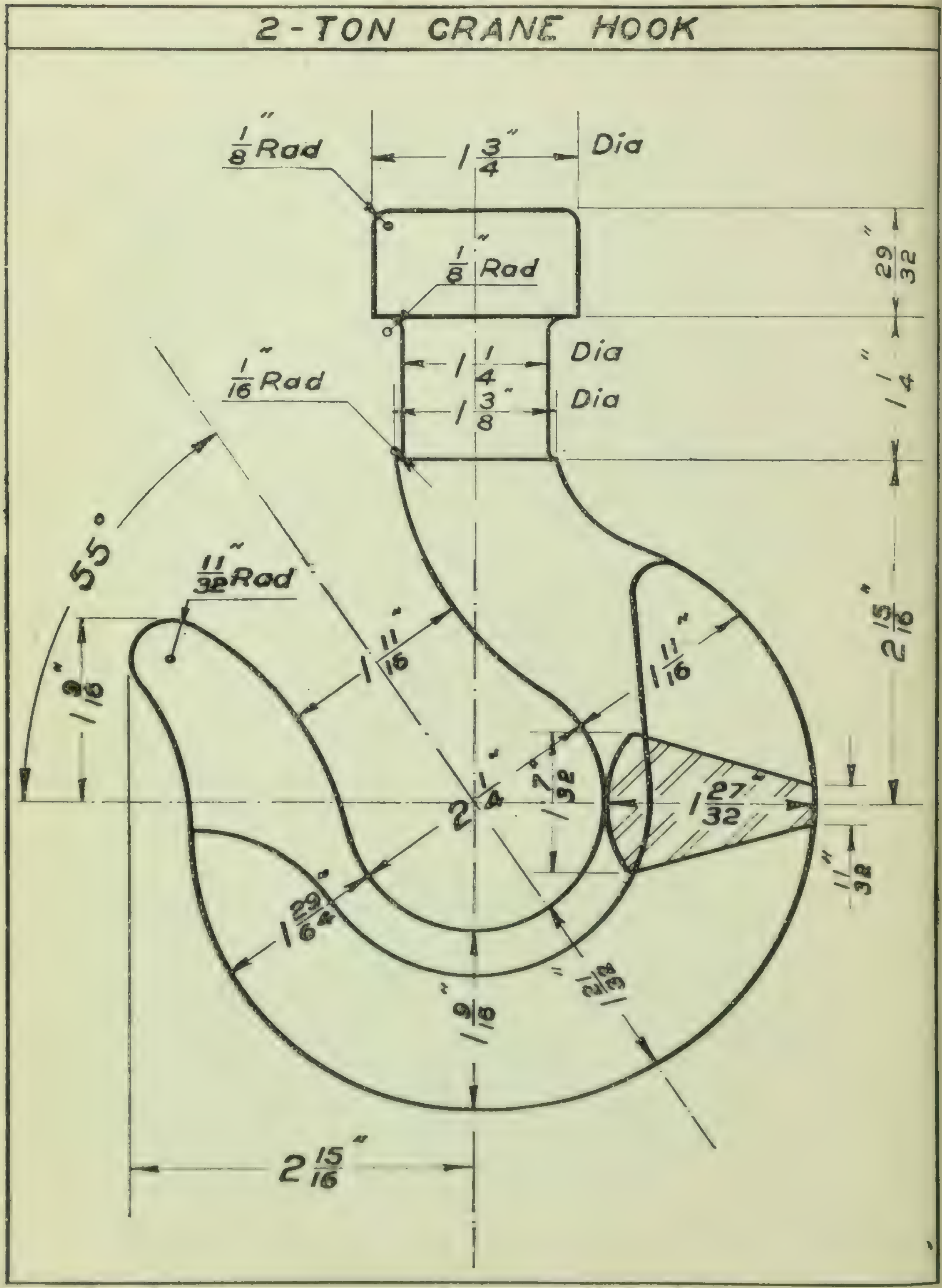
Diagram 6 shows the straight lines joining the arcs and circles.

Exercise.

1. Trace the wrench you have drawn.
2. Draw and trace the rail section, page 63.
3. Draw and trace the crane hook, page 66.



STAGES OF TRACING – A LATHE DOG



Tracing Exercise. Test 2.

REPRESENTATION OF SCREW THREADS WITH STRAIGHT LINES

Various threads are used so frequently in detail drawings that a simple conventional method of representing them has been adopted. The top of a thread is a path around a cylinder making a uniform progression which when viewed takes the form of a helical curve. This method of representation is shown on page 93. When drawing threads time is saved by representing the helical curve by a straight line.

The photograph at (C) shows an external right-hand thread and the photograph at (B) an internal thread. The nut (B) made to fit the screw (C) has been cut through at its centre showing the section of a U.S.S. thread (page 68).

Small threaded parts (Diagram 1) may be represented as shown, with lines drawn at right angles to the axis. This method may be used to advantage for parts ½″ diameter or less. It is not a true representation of a thread but is sufficient to show that the part is threaded.

External and Internal right-hand single threads are shown usually as illustrated in diagrams 2 and 3. The inclination of the thread should first be marked one-half the pitch, this gives the slope of the thread to which the set square is set to slide on the tee square. The remaining threads are drawn parallel to this from the pitch points previously marked from a rule, 1/16″ or ⅛″ divisions being commonly used. The exact pitch of a thread need not be marked for drawing purposes as long as it is stated in a notation such as 1″ - 8 thds. U.S.S. (R.H.)

Section of a threaded nut (Diagram 3). This shows the back half of the thread, that is why it is inclined opposite to the external thread to which it fits, (see dotted line in diagram 2).

Inclination of right and left-hand thread (Diagrams 2 and 4.) If the axis is vertical the external right-hand thread inclines to the right while an external left-hand thread inclines to the left.

Representation of large V thread (Diagram 6). Threads on work 2″ diameter or over are usually represented with the V of the thread shown. The scale shows the method of locating the pitch points for 4½ threads per inch or any other size. Always represent a right-hand thread starting from the bottom left-hand corner, then mark the inclination one-half the pitch. Draw the V of the thread with the 30° set square on both sides to get the inclination of the root of the thread which is greater than that of the top of the thread. Photo of large U.S.S. thread at (A), page 68.

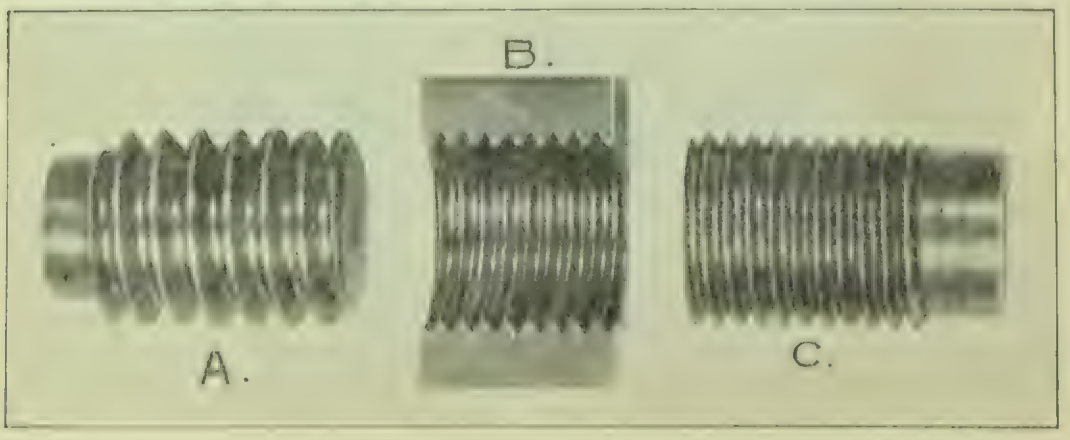
Sections of Square, U.S.S. and Acme threads (Diagrams 7, 8, 9, and Photo D). These are common threads used. The square thread is simple to lay out. The U.S.S. thread is enlarged below in diagram 11 to show how it is built up. For drawing purposes the Acme thread may be drawn with an inclusive angle of 30° which may be obtained by using 45° and 30° set squares (diagram 12) together on the tee square, making an angle of 75° or 15° from a line at right angles to the axis of the thread.

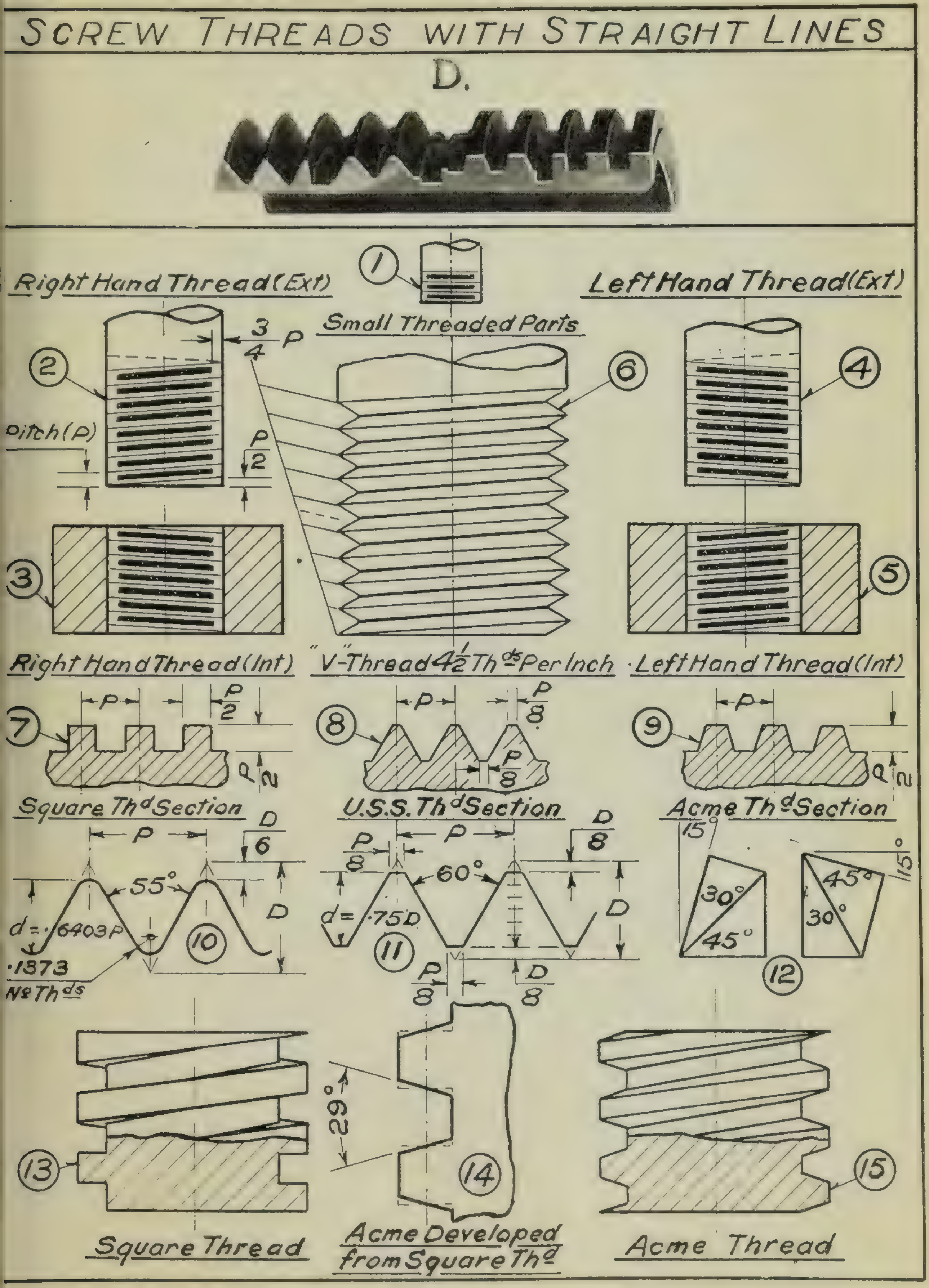
The Whitworth Thread (Diagram 10). This thread is the British Standard Thread. It has an angle of 55° and is round top and bottom, 1/6 D.

Representation of a square threaded screw (Diagram 13). First draw the thread as if in section with a thread on one side opposite a space on the other side, then join the tops of the threads and the bottoms of the threads where they would be seen. Leave bottom half in section and upper half in elevation.

Representation of an Acme Threaded Screw (Diagrams 14 and 15.) Diagram 14 shows how an Acme thread is developed from a Square thread. Mark the pitch points of the thread first, then the inclination, then construct one thread as shown in diagram 14 and apply the proportions to the other threads and join root to root and top to top of the thread. Use the 45° and 30° set squares to draw the side of the thread at 15° which will give an approximate inclusive angle of the thread of 30° instead of the correct angle of 29°, but this is satisfactory for drawing purposes. Leave one-half in section.

Exercise: On a 9″x12″ sheet of drawing paper, copy the diagrams given, but represent 3½ threads per inch instead of the 4½ threads per inch as shown in diagram 6. Rearrange the diagrams to suit your sheet because of space provided for photographs.




SCREW THREADS WITH STRAIGHT LINES
D.
①
Small Threaded Parts
Right Hand Thread (Ext)
Left Hand Thread (Ext)
②
③
④
⑤
⑥
$\frac{3}{4}$ P
pitch (P)
$\frac{P}{2}$
Right Hand Thread (Int)
"V"-Thread 4½ Th^ds Per Inch
Left Hand Thread (Int)
⑦
⑧
⑨
P
$\frac{P}{2}$
$\frac{P}{8}$
Square Th^d Section
U.S.S. Th^d Section
Acme Th^d Section
$\frac{D}{6}$
55°
d = .6403P
.1373 / Nº Th^ds
D
⑩
$\frac{D}{8}$
60°
d = .75D
⑪
15°
30°
45°
⑫
29°
⑬
⑭
⑮
Square Thread
Acme Developed from Square Th^d
Acme Thread

FREEHAND SKETCHES OF SCREWED FASTENINGS

The object of this lesson is to make the student familiar with some of the common screwed fastenings. All that is needed is a piece of paper 9″x12″ and an HB pencil. Duplicate the sketches shown by drawing freehand, and note the particular feature of each form of fastening. These fastenings are used as temporary fastenings for various parts of machines, so that the machines can be taken apart if necessary and re-assembled.

Bolts. Three types of bolts are shown in diagrams 1, 2 and 11. A bolt holds parts together by exerting a pressure on the parts between the head and the nut. Standard bolts are made with a "bright" finish, that is, they are machined all over, or a "black" finish (caused by the forging) with only the threads cut or machined. The heads of these forged bolts are "upset" while hot.

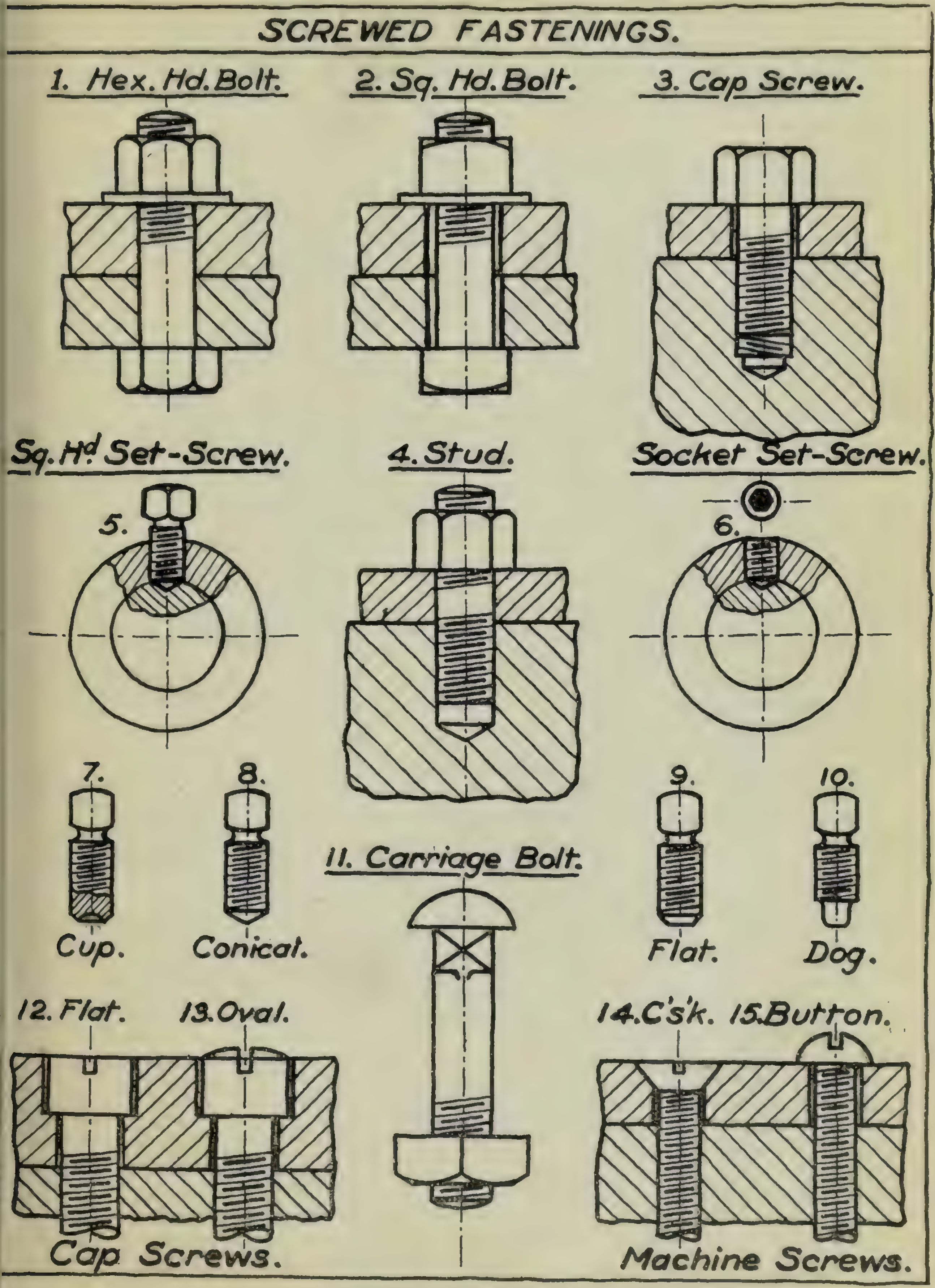
Washers are shown being used in diagrams 1 and 2. They are used to give a smooth bearing surface to the under side of the nut. The diameter of the washer is a little more than the distance across the corners of the nut. The washer is one-eighth the thickness of the bolt.

Hexagonal-Headed Bolt. Diagram 1. There are many forms of bolt heads used, but the hexagonal-headed form is usually adopted on bright finished bolts, although forged bolts may have either square or hexagonal heads. The hexagonal-headed bolt has the best appearance and is the most convenient form to use when tightening with a spanner. It is stronger than a square form because it has a greater amount of metal in its head and nut.

Square-Headed Bolt and Nut. Diagram 2. This is the common form of black or forged bolt, and is used on general work where a high class finish is not required. The long square face gives a greater contact than a hexagonal face when being turned with a wrench.

Hexagonal-Headed Cap Screw. Diagram 3. Cap Screws have different forms of heads. The one illustrated in this diagram is a bright finished screw, and is used to press two parts together by exerting pressure on the plate from the under side of its head or cap. Cap Screws or Studs generally are used because the lower tapped piece of metal is too thick to be drilled for a bolt, or that it would be impossible or inconvenient to use a bolt. A space must be left between the end of the Cap Screw and the bottom of the tapped hole for clearance, so that the pressure may be exerted by the head only.

Stud Bolt. Diagram 4. A Stud is a rod of metal threaded at both ends. The Stud is screwed into a tapped hole with a pipe wrench or Stud Driver. It must be secured tightly in the tapped hole so that when the nut is unfastened the Stud will remain in



Freehand Sketches

place. This feature makes it more desirable than a Cap Screw, because if a Cap Screw is frequently removed the tapped hole in some expensive part may be damaged. The Stud remains in the tapped hole and the nut only is taken off to separate the machine parts.

Square-Headed Set Screw. Diagram 5. A Set Screw may be used as shown to fasten a collar to a shaft so that it may rotate with the shaft or be prevented from moving along the shaft. The Set Screw exerts pressure on its end, forcing the collar to grip the shaft. Various points of Set Screws are shown in diagrams 7, 8, 9 and 10. Set Screws are made of hardened steel to prevent the point from being crushed under the pressure.

Safety Socketed Set Screw. Diagram 6. When Set Screws are used on rotating shafts, it is advisable to use the socketed type. because the square head type protrudes from the cylindrical collar and may catch in clothing. This has been the cause of many serious accidents. Use the safety type where possible. Slotted heads are sometimes used. Headless Set Screws are called **Grub Screws.**

Carriage Bolt. Diagram 11. The under side of the round head of this forged bolt has a square form (shown by diagonal lines) to prevent the bolt from turning while the nut is being tightened. This type of bolt is used when fastening metal to wood, or wood to wood. The smooth round head gives a free surface as compared to a square or hexagonal-headed bolt. The Carriage Bolt is usually driven with a hammer into the wood after drilling the hole, thus forcing the squared portion into the wood and preventing the bolt from turning.

Fillister-Headed Cap Screws. Diagram 12, 13. These Cap Screws have cylindrical heads and are both turned into a counterbored recess with a screwdriver. Cap Screws may have heads formed in the following ways: Hexagonal, Square, Oval and Flat Fillister, Button or round and Countersunk 70°. All types of heads are not available in the larger diameters.

Machine Screws. Diagrams 14, 15. These screws are mostly used on small machine parts where great strength is not desired. The largest diameter is .450″, and the smallest .060″ diameter. The types of heads available are Oval and Flat Fillister, Button and Countersunk 82°.

Tapped Holes. Two methods of representing the bottom of tapped holes are shown, one in diagram 3 which is correct, and one in diagram 4 which is approximate.

Exercise: On a 9″x12″ piece of paper, sketch freehand the screwed fastenings. Do not use any mechanical aid such as rules or set squares. The circles may be obtained approximately by the use of washers or any round object.

TAP DRILL SIZES FOR U. S. STANDARD THREADS

These tap drill diameters allow approximately 75% of a full thread.

Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill
¼	20	13/64	13/16	10	45/64	1⅜	6	1 7/32
5/16	18	¼	⅞	9	49/64	1½	6	1 11/32
⅜	16	5/16	15/16	9	53/64	1⅝	5½	1 7/16
7/16	14	23/64	1	8	⅞	1¾	5	1 35/64
½	13	27/64	1 1/16	8	15/16	1⅞	5	1 43/64
9/16	12	15/32	1⅛	7	63/64	2	4½	1 25/32
⅝	11	17/32	1 3/16	7	1 3/64	2¼	4½	2 1/32
11/16	11	19/32	1¼	7	1 7/64	2½	4	2¼
¾	10	41/64	1 5/16	7	1 11/64	2¾	4	2½

TAP DRILL SIZES FOR S. A. E. STANDARD THREADS

These tap drill diameters allow approximately 75% of a full thread.

Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill
¼	28	7/32	9/16	18	33/64	1	14	15/16
5/16	24	9/32	⅝	18	37/64	1⅛	12	1 3/64
⅜	24	21/64	11/16	16	⅝	1¼	12	1 11/64
7/16	20	25/64	¾	16	11/16	1⅜	12	1 19/64
½	20	29/64	⅞	14	13/16	1½	12	1 27/64

TAP DRILL SIZES FOR A. S. M. E. STANDARD MACHINE SCREWS

These tap drill diameters allow approximately 75% of a full thread.

Standard Machine Screws

No. of Screw	Diam. of Tap	Threads per inch	Tap Drill Diam.	Drill No. or letter	No. of Screw	Diam. of Tap	Threads per inch	Tap Drill Diam.	Drill No. or letter
0	0.060	80	0.0465	56	12	0.216	28	0.180	15
1	0.073	72	0.0595	53	14	0.242	24	0.201	7
2	0.086	64	0.070	50	16	0.268	22	0.221	2
3	0.099	56	0.081	46	18	0.294	20	0.242	C
4	0.112	48	0.089	43	20	0.320	20	0.266	H
5	0.125	44	0.1015	38	22	0.346	18	0.290	L
6	0.138	40	0.113	33	24	0.372	16	0.302	N
7	0.151	36	0.120	31	26	0.398	16	0.332	Q
8	0.164	36	0.136	29	28	0.424	14	0.348	S
9	0.177	32	0.147	26	30	0.450	14	0.377	V
10	0.190	30	0.157	22					

DRAWING A NUT AND BOLT

You are already familiar with some forms of bolts since you have sketched the samples presented in the lesson on "Screwed Fastenings." The object of this lesson is to give you an opportunity of making scale drawings of bolts and nuts, by finding your own dimensions from the data provided in this lesson. The three photographs show at (A), a square headed bolt; at (B), a (S.A.E.) bolt; and at (C), a hexagonal headed bolt.

Drawing from Data. The diagrams 1 to 4 do not give dimensions. The proportions of a bolt and nut are calculated from the diameter of the bolt (D).

Distance Across Flats of Head and Nut. This is found by multiplying the diameter of the bolt by one and one-half, and adding to this amount one-eighth of an inch. The distance across the flats is represented by (F), so that (F)=1½D+⅛″. Because of the constant ⅛″ being added to all calculations, the relation of the inner corners of the nut and head will vary in comparison with the lines representing the diameter. Draw a circle for the end view of the head, diagram 1, with a diameter equal to (F), then construct the hexagon and project the corners of the hexagonal head over to the elevation of the head and nut.

Chamfer of Bolt Heads and Nuts May be Conical or Spherical. Machine or "bright finish" bolts have a chamfer of 45°. Forged or "black finish" bolts have a chamfer of 30°. The intersection of the chamfer with the sides of the head and nut are represented as circular arcs, while actually they are conic sections, but the circular arc is used to approximate the intersection. The working side of some bolt heads and nuts are made circular as shown in diagram 4 to give a uniform smooth bearing on the surface of the work to be held.

Drawing Details of Bolts and Nuts. These are sufficiently represented in diagrams 1 to 4 with the exception of (C), diagrams 1 and 3, which is found by multiplying (F) by 2 different constants, one for square and one for hexagonal head. These are shown in summary below.

With your previous experience in representing threads you should be able to do the following exercise:

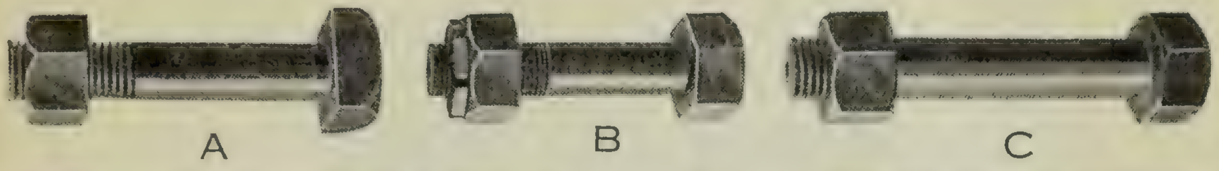
Proportions of Hexagonal Head Bolt and Nut (Diagrams 1 and 2). F=1½D+⅛″. C=F×1.155.

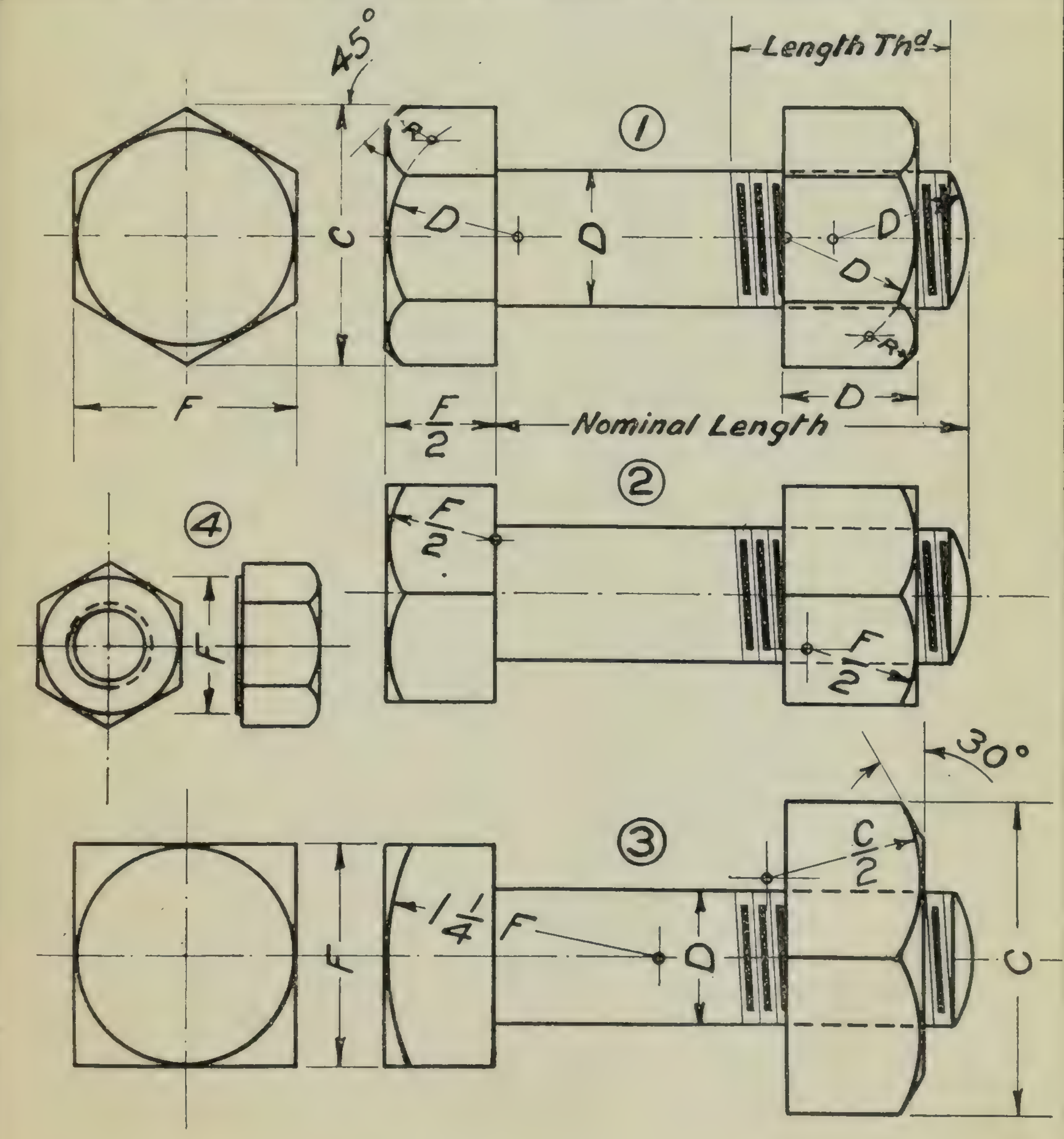
Approximate Proportions. F=1¾D. C=2D.

Proportions of Square Head Bolt and Nut (Diagram 3). F=1½D+⅛″. C=F×1.42 approximately. C=F×1.414 exactly.

Exercises: (1) On a 9″x12″ piece of paper draw 3 views of a 1″ diameter bolt as shown in diagrams 1 and 2. Length of the bolt 3½″. Draw this on the upper half of the paper and put in dimensions. (2) Draw two views of a square head bolt and nut as shown in diagram 3. Diameter of this bolt ⅞″, length of bolt 3″. Draw this on the lower half of your sheet and put in dimensions.

DRAWING A NUT & BOLT





WHEELS AND PULLEYS

A few examples of wheels and pulleys are given in this lesson. Pulleys are usually made of cast iron but of late years a great number of pressed steel pulleys have been used as they can be very conveniently clamped to a shaft. In addition to this they are light in weight and easily handled. Sometimes a pulley is made up with the wrought iron spokes cast into the hub when hot and they are provided with a wrought iron rim. Cast pulleys often have curved arms because through unequal cooling and therefore unequal contraction the arms are generally in a state of tension or compression. The straight arms if not properly designed are likely to yield to these strains which will cause a break of the arm or where the rim joins the arm. The curved arm yields under strain and prevents possible breakage. Unequal number of arms are often used to meet the same conditions. The cross section of cast iron pulley arms is usually elliptical although other shapes are used as shown in this lesson.

A lathe countershaft is shown in diagram 1. The countershaft is fastened to the overhead structure through two open hangers. The bearings are held securely in the hangers and end play of the shaft is prevented by two collars fastened to the shaft with socketed safety set screws.

A cone pulley or stepped pulley is shown at (A). Each step is crowned so that the belt will ride on the high point of the crown which tends to prevent the belt from running off.

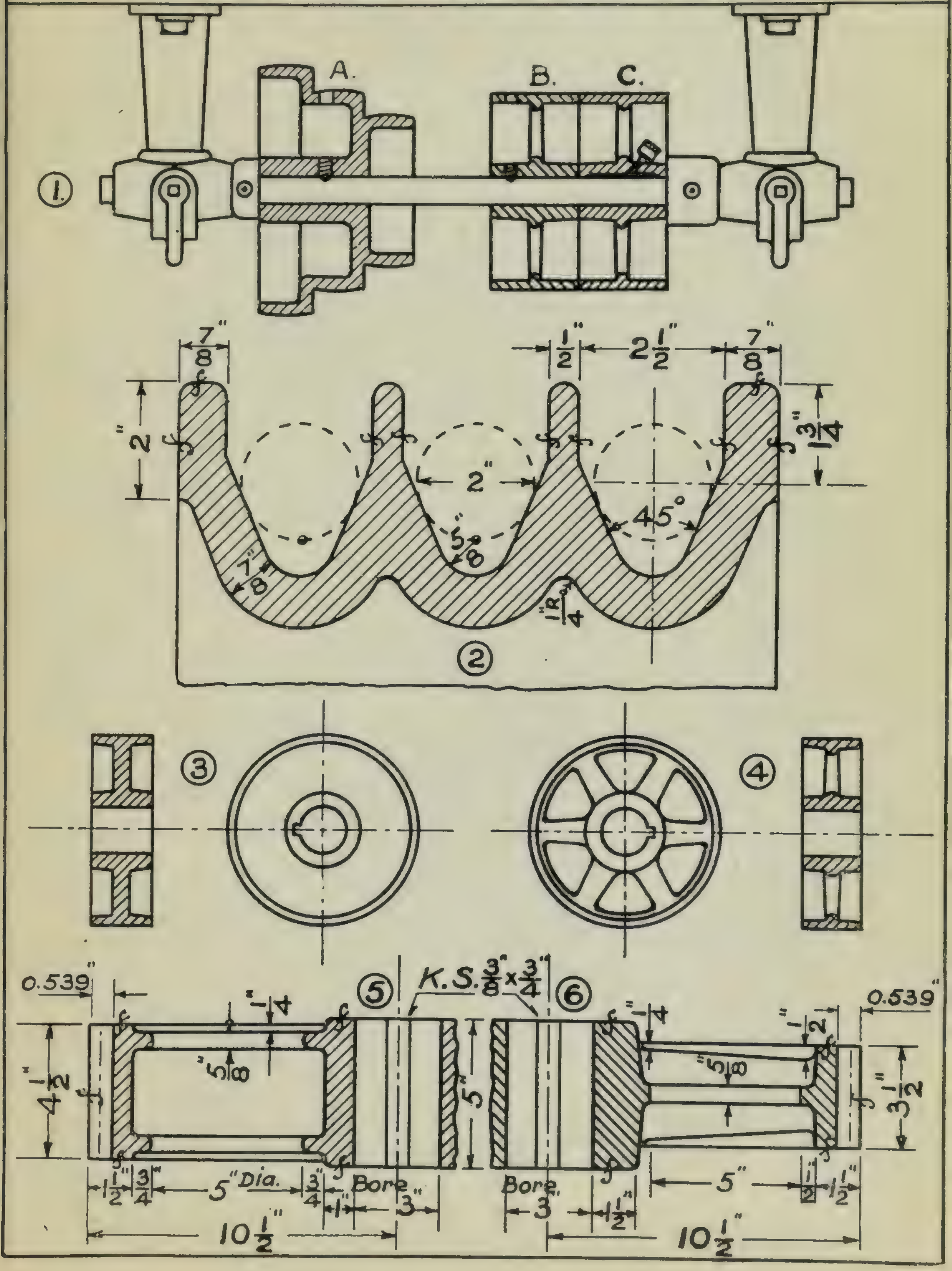
A fast pulley is shown at (B) with a flat rim. Sometimes the pulley is crowned. This pulley is fastened to the shaft with a set screw so that it may be driven from the main shaft to turn the countershaft.

A loose pulley is shown at (C). This pulley is flat also, but may be crowned. Sometimes the loose pulley is slightly smaller than the drive pulley so that the belt may run free on it. This pulley must be lubricated so that it may run on the stationary shaft. A grease cup is shown providing grease which is distributed through a groove to the bore of the pulley.

A rope pulley is shown in diagram (2). Ropes are sometimes used for transmitting power. The pulley is made of cast iron and the rim is grooved as shown. The V-angle is usually 45° and the rope rests on the sides of the groove but not on the bottom, so that it is wedged in to give a good drive.

A solid webbed pulley is shown in diagram 3; note the "draft" on the cast pulley.

WHEELS AND PULLEYS.



A spoked pulley is shown in diagram 4 with spokes that are elliptical in section and tapering toward the rim; width, ⅜″ taper per ft. per side; thickness, 3/16″ taper per ft. per side. Observe the bead where the spokes meet the rim. A spoked wheel is always shown as in section in diagram 4. Sometimes a boss is provided on the hub to give extra metal where the keyway is cut.

Heavy duty gear wheels are shown in diagrams 5 and 6. Diagram 5 shows a wheel with two webs, with six holes circular in shape cored in the webs, to lighten the wheel and still allow sufficient strength for heavy work. The spokes in diagram 6 are six in number and have ribs cast on either side of each spoke to give strength. All rib thicknesses are equal.

Exercises.

1. On a 9″ x 12″ piece of paper sketch the countershaft shown in diagram 1 and diagrams 3 and 4. Arrange your sketches to suitably fit the paper. On the same sheet draw diagram 2. Scale half full size.

2. On a 9″ x 12″ piece of paper draw one-half of each wheel in plan and in section as shown. Arrange the drawings to suit the paper with proper spacing. Scale one-quarter full size. Put on dimensions, notations, and a title.

TAPER APPLICATIONS

A few examples of taper applications are shown on the opposite page. The student must be able to distinguish the difference between taper per foot on the diameter of work, and taper per side.

Taper per foot on the diameter of work is illustrated in the examples shown, with a centre line representing the axis of round work.

E.g., "½″ per ft. taper," means that in one foot of length the difference of the diameters of the large and small ends would be ½″.

Taper per foot per side is illustrated in the examples shown that do not have a centre line, because the tapered parts shown are flat. The cotter, the gib and cotter, and the gib key are the examples given.

E.g., "⅛″ per ft. taper on the gib key," means that if the key were one foot long, it would have a rise of 1 in 96, or ⅛″ per ft. The triangles at (A) and (B) show the difference in the two kinds of tapers mentioned above. Triangle (A) shows ⅛″ per ft. per side and triangle (B) shows ⅛″ per ft. on the diameter.

Note that triangle (A) with ⅛″ per ft. per side is the same taper per side as the taper pin and yet the taper pin is ¼″ per ft. on the diameter.

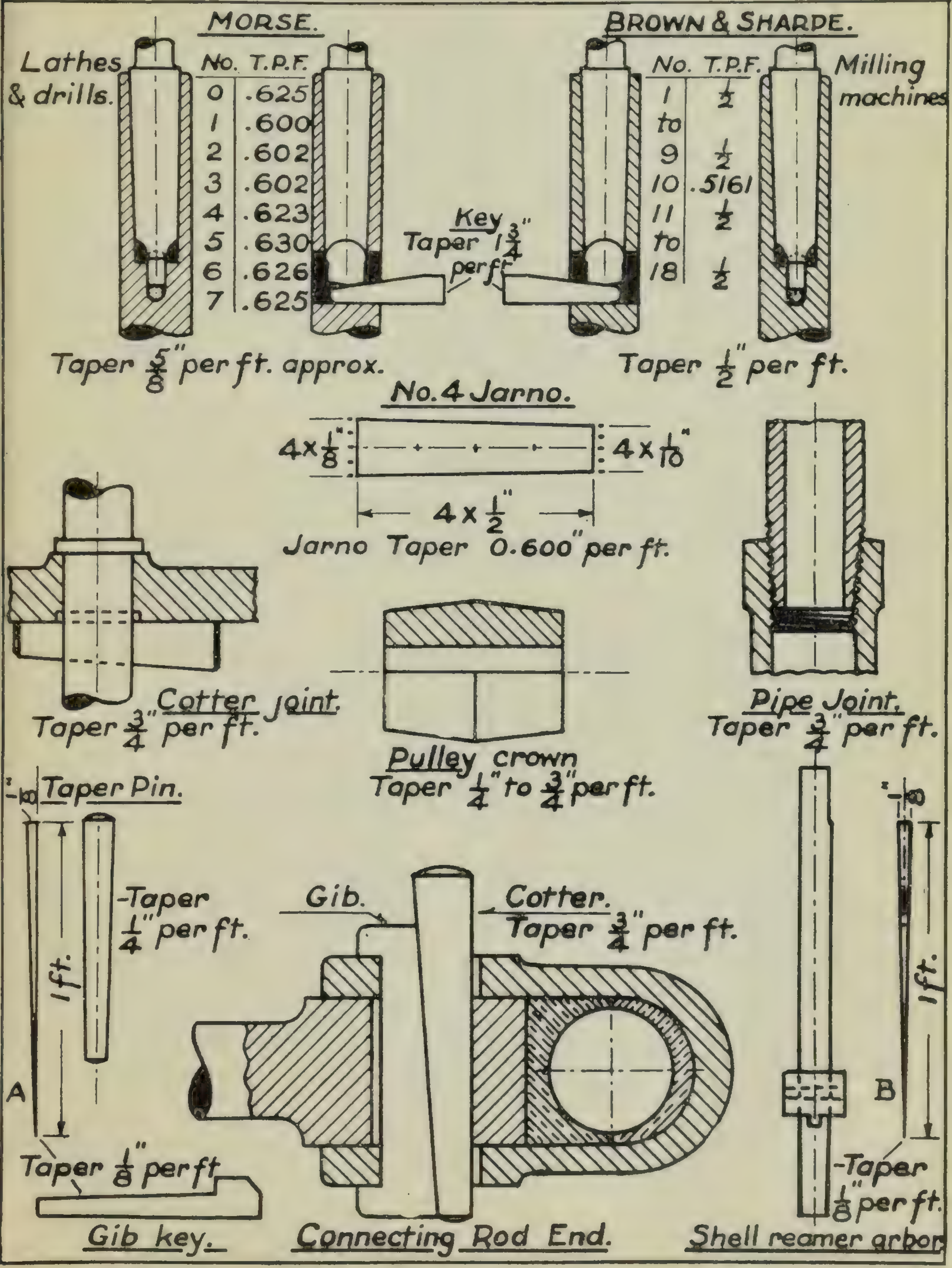
The Jarno taper of 0.600″ per ft. is standard for all sizes so that the proportions of the job can be easily calculated once the number is known.

E.g., No. 4. The job will be four ½″ long, the big end four ⅛″ diameter, the small end four 1/10″. in diameter.

The pulley crown is sometimes tapered as shown and sometimes it is made with the crown a part of a circle. In this case the rise of the crown would be given or the radius specified.

Exercise. On a 9″ x 12″ piece of paper, sketch freehand the examples given and put in the figures and notations shown.

TAPER APPLICATIONS.



MORSE.

No.	T.P.F.
0	.625
1	.600
2	.602
3	.602
4	.623
5	.630
6	.626
7	.625

Taper $\frac{5}{8}$" per ft. approx.

BROWN & SHARPE.

No.	T.P.F.
1	$\frac{1}{2}$
to	
9	$\frac{1}{2}$
10	.5161
11	$\frac{1}{2}$
to	
18	$\frac{1}{2}$

Taper $\frac{1}{2}$" per ft.

No. 4 Jarno.

Jarno Taper 0.600" per ft.

Cotter joint.
Taper $\frac{3}{4}$" per ft.

Pipe Joint.
Taper $\frac{3}{4}$" per ft.

Pulley crown
Taper $\frac{1}{4}$" to $\frac{3}{4}$" per ft.

Taper Pin.

Taper $\frac{1}{8}$" per ft

Gib key.

Connecting Rod End.

Shell reamer arbor

LOCKING DEVICES

A screw consists of a thread cut around a cylinder in a continuous inclined fashion, so that the principle of the inclined plane is used to exert pressure on work by screwing a nut on to the threaded part. Many applications of such work have already been given so that one should realize that the pressure reactions from the work to the nut (and in many cases constant vibrations) tend to force the nut back up the incline of the screw. If the nut is loosened in this manner, the consequences would be very serious. To prevent such a possibility, locking devices are used, and a few important examples are illustrated in this lesson.

Types of locking devices. Locking devices mav be divided into two types, the **positive type** as shown in diagrams 1, 2, 6, 7 and 9, and the **surface friction type** as shown in diagrams 3, 4, 5 and 8. It is well to note that a threaded part, serving as a nut, can be hexagonal, square, and other shapes with either a right or left-hand thread, as requirements demand.

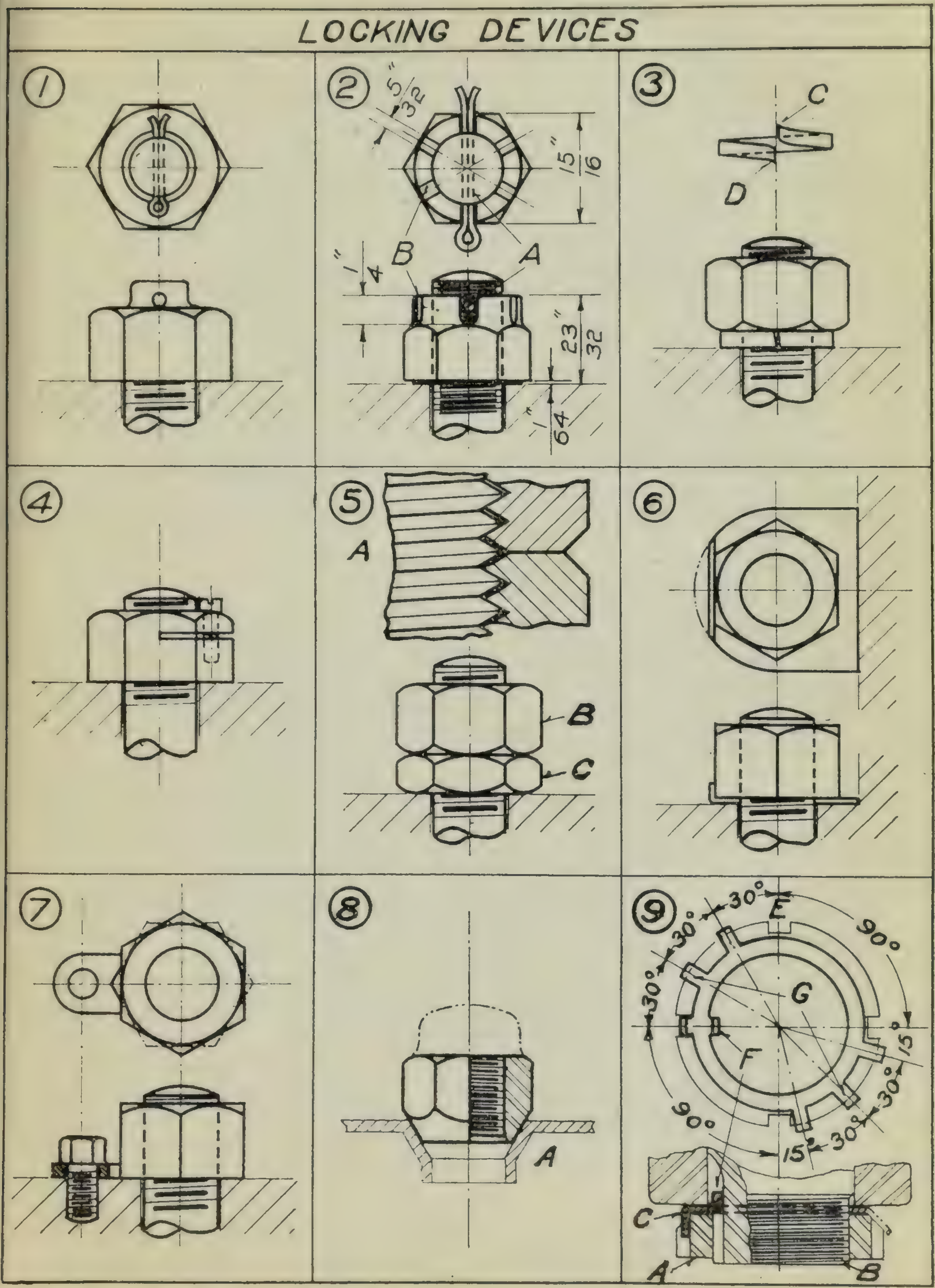
Split pin (Diagram 1). To use a split pin, a hole is drilled through the screw and a split pin is passed through the hole. The legs of the pin are opened so that it cannot slip out. This device prevents the nut from coming off the screw, but still allows the nut to be turned on the screw away from the underside of the split pin.

Castellated nut or "Castle nut" (Diagram 2). This type usually is designed to S.A.E. (Society of Automotive Engineers) standard, and is used largely in the automotive and aircraft industry.

It provides six positive locking positions combined with a fine thread. The slots in the nut are shown at B and the split pin is passed through a convenient slot in the nut and the hole in screw at A. A wide range of adjustment is provided due to the depth of the slots B being about twice as deep as the diameter of the split pin.

Spring lock washer (Diagram 3). This washer is a heat-treated helical-formed steel washer of a rectangular cross-section shape. The upper and lower ends of the washer are bent at C and D to form a raised edge. When the nut is tightened against the washer as shown, the sharp edges penetrate the under face of the nut and the upper face of the material being gripped, this in addition to the reaction of the spring tend to prevent the nut from becoming slack due to a constant vibration, such as would be the case in an automobile and other types of engines.

Split nut (Diagram 4). This partially split nut is fitted with a clamp screw shown as a cap screw clamping the upper and lower parts of the nut together at its weakest point. The upper part of the nut presses against the upper side of the threads on the screw and pinches the threads, thus preventing the nut from becoming


LOCKING DEVICES
①
②
5"/32
15"/16
B
A
1"/4
B
A
23"/32
1"/64
③
C
D
④
⑤
A
B
C
⑥
⑦
⑧
A
⑨
30°
30°
E
90°
30°
30°
G
F
15°
30°
30°
90°
15
30°
C
A
B

loose on the screw. This type is used mostly on round nuts on machine spindles, but will not resist excessive vibration.

Lock nuts (Diagram 5). Two nuts used as shown, one pressing against the other to prevent the nuts from becoming loose on the screw. The thin nut (C) is shown in contact with the work and the standard nut (B) above. This position gives the greatest possible locking action, although it is inconvenient to use a thin wrench on the lower nut; because of this the thin nut is often placed on the top of the thick nut. The sectional diagram (5A) shows the locking effect produced by the nuts, forcing the threads apart and binding on the threads of the screw. Lock nuts have the advantage of being locked with varying pressure on the surface of the material being gripped, or they can be locked together in an isolated position on a screw to form a stop or collar.

Locking plate (Diagram 6). A simple locking plate is shown where the adjacent shoulder is used to prevent the plate from turning. The most accessible edge of the plate is bent up to suit a flat of the nut, when it is finally tightened. This type of locking plate should not be used a second time, as the bent-up edge would break off.

Diagram 7 shows another locking plate made to fit against a flat or against the corners of the nut.

Self locking nut (Diagram 8). This nut is used frequently on automobiles for demountable wheels. The nut has a bevelled or conical face which fits into a pressed steel seat (A) which gives a spring reaction in addition to the wedging action of the nut. This type of nut is sometimes made as shown by the dotted line as an acorn shape to give protection and keep out foreign matter.

Adjustable lock washer (Diagram 9). This lock washer is used on anti-friction bearings to lock the nut (A) to the threaded part (B). The round nut has four equally spaced slots shown at (E) which serve for turning the nut with a key. The washer has one lug (F) protruding inside the bore, and six external lugs (G) which are all bent slightly to fit the inside bevel of the nut face. The lugs (G) are so spaced that they will give twenty-four locking positions at every 15° turn. When one lug is bent into one of the four slots (E) in the nut, the nut is locked as shown also at (C). A key way is cut into the shaft into which the internal lug (F) fits, this prevents the lock washer from turning. A fine threaded nut provides a very close adjustment combination for first class work. As the lugs are bent cold, the lock washer should not be used a second time.

Exercise.

On a 9″ x 12″ piece of drawing paper draw the examples given. Scale full size. Obtain your sizes with a 5/8″ to 1″ scale from the printed diagrams and use your knowledge of bolt and nut proportions.

EXAMINATION QUESTIONS.

1. State how you could draw arcs, fillets and circles without the use of a pair of compasses.
2. Write out a list showing the order in which you would make a tracing from a given drawing.
3. Why is a bridge washer used?
4. What is the difference between a section and sectional elevation?
5. Make a list of the various methods of making holes in metal.
6. What is the advantage of using a "core" when casting metal?
7. Why is heat treatment of metals considered of great importance?
8. What metals are case-hardened, and what metals are hardened and tempered?
9. Define "hardening" and "tempering."
10. How would you case-harden a piece of iron if you were out in the country?
11. State the various applications of "shrinkage" that you know of.
12. Why is it necessary to put finish marks and notations on drawings?
13. Why are reference numbers necessary on a drawing?
14. Write out in full the meaning of:— "Tap ⅜″—16 U.S.S. (R.H.)."
15. Why is it necessary to spot face a boss?
16. Lay out a "title" for a drawing and state what each column is used for.
17. How would you distinguish a right-hand from a left-hand thread?
18. Sketch an equilateral triangle and show how a section of a U.S.S. thread may be represented by first drawing the triangle.
19. Why does a factory inspector insist on the use of socketed set-screws, if possible, on rotating parts?
20. Why does a carriage bolt have a round head and a square shank under the head?
21. Why are studs used in some places in preference to cap screws?
22. Why is it advisable to use a washer under a nut when using a bolt?
23. Write out the calculations necessary to obtain the proportions of a ⅞″ diameter bolt.
24. Why does the distance between the two lines representing the inner corners of a hexagonal bolt head vary in relation to the diameter of the bolt?
25. Sketch the cross-section of the arms of two types of pulleys.
26. How can you decide from a section drawing whether a pulley or wheel has a solid web or is spoked?
27. Sketch in section the rim of a flat pulley and a crowned pulley. Why is crowning a pulley an advantage in some cases?
28. Sketch in section showing the proportions, the following threads: (a) Square, (b) Acme, (c) U. S. Standard, (d) Whitworth.
29. Sketch in section a screw and nut in mesh when tap-drilled for a 75% depth of thread.
30. List the various taper applications you know of, and state the taper per foot used.
31. List the various locking devices you know of.

SKETCHING TYPES OF BOLTS

Tee Headed Bolt (Diagram 1). This type of bolt head is used to fit in tee slots of machines. The bolt is prevented from turning when the nut is being tightened by the square part of the bolt near to the tee head. This bolt is used frequently in holding down work while it is being machined.

Countersink Headed Bolt (Diagram 2). The head of this bolt wedges into a corresponding tapered hole in the work to be bolted. The friction so obtained helps to prevent the bolt from turning. Sometimes a slot is provided as shown so that a screwdriver may be used to prevent the bolt from turning while the nut is being tightened.

Eye Bolt (Diagram 3). This bolt is screwed into machines so that they can be lifted. This bolt may frequently be seen in motors so that a bar may be passed through the eye for lifting it. With heavier machines a chain is used suitable for lifting with a crane.

Cheese Headed or Cylindrical Headed Bolt (Diagram 4). A pin is fastened beneath the head of this bolt to prevent the bolt from turning.

Round or Cup Headed Bolt (Diagram 5). This bolt is prevented from turning by forging a snug beneath the head.

Taper Bolt (Diagram 6). This bolt is like a countersink-headed bolt with the countersink portion lengthened. It is used to fasten the couplings of a steamship screw shaft. It has no projecting head and can easily be drawn in to give a tight fit in the holes.

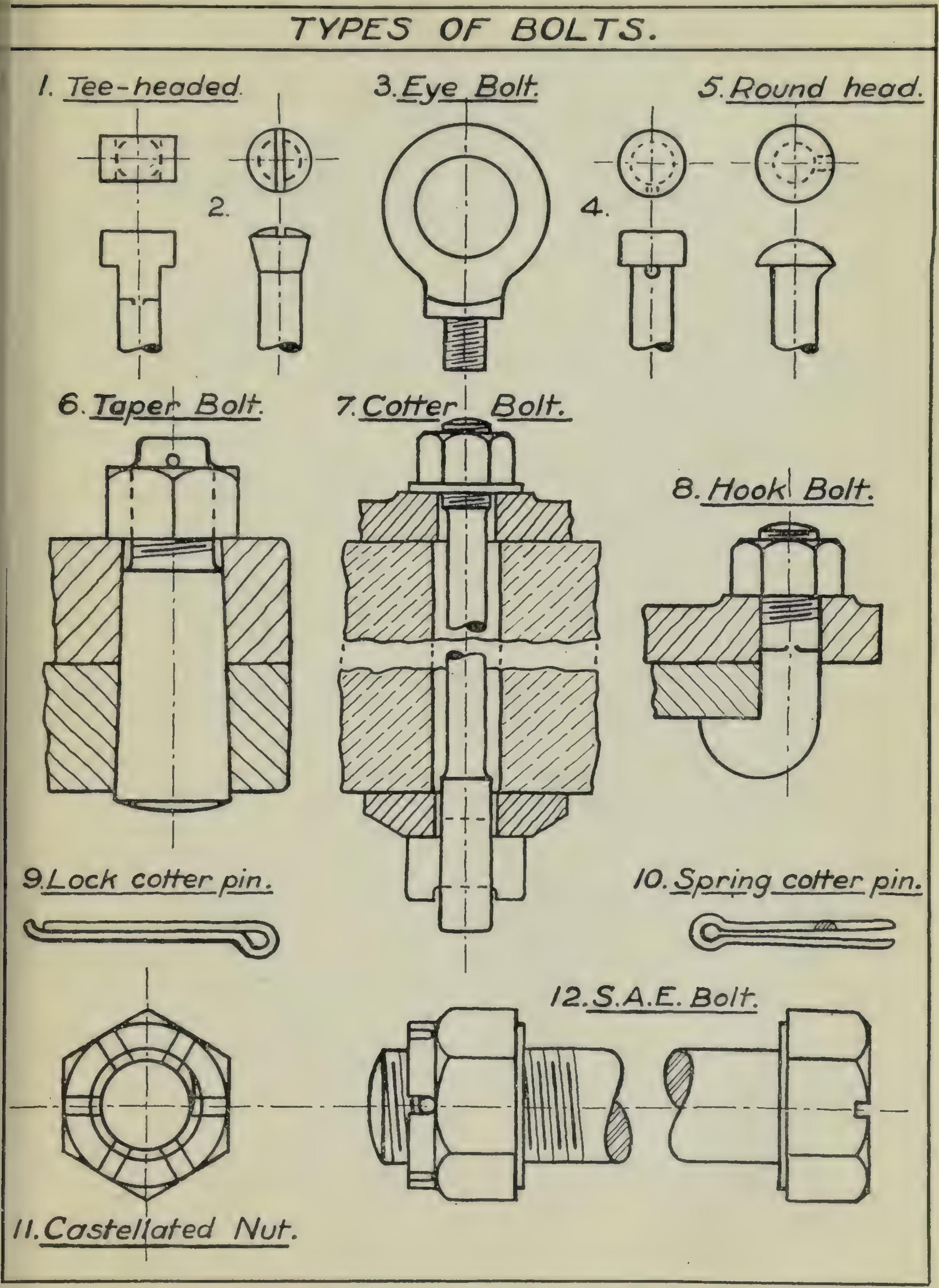
Cotter Bolt (Diagram 7). This bolt is very suitable to fasten down large engines or heavy machines to brick or stone foundations. The bolt is enlarged at both ends to keep a uniform strength throughout, due to the weakening action of the thread cut on one end and the rectangular slot cut in the other end to receive the cotter, which forms a head to press against the circular cast iron plate.

Hook Bolt (Diagram 8). The square part of this bolt fits into a square hole to prevent it from turning. The bolt holds the edge of the piece of metal being held, so that it can be slipped away as soon as the nut is loosened.

Cotter Pins (Diagrams 9 and 10). These pins are used to lock a nut on a bolt such as shown in diagram 12. A hole is drilled through the S.A.E. bolt and the pin passes through the hole and the castellations, thus preventing the nut from turning after it has been tightened.

S.A.E. Bolt (Diagram 12). This type of bolt is used in automotive work. Finer threads are used on S.A.E. bolts than on U.S.S. bolts to give fine adjustment. The nut and head of the bolt is given a circular seat by reducing the hexagonal stock 1/64″ as shown. S.A.E. bolts are made of special steel having great tensile strength. The screw and plain nuts are left soft but the castellated nuts or "castle-nuts" are sometimes case-hardened.

Exercise. Sketch bolts as shown on 9″ x 12″ paper.



Freehand Sketches

DETAIL AND ASSEMBLY DRAWING

This lesson will give the student an opportunity to make detail drawings of a simple machine unit as would be provided for purposes of manufacture. It is well to keep in mind that drawings give instructions to workman as to shape, dimension, finish, and sometimes the heat treatment required for the parts to be made. Put yourself in the workman's place and check carefully to see that the instructions you give are sufficient to ensure that the article will be properly made.

Detail Drawings. Each component part of the machine is drawn separately in a detail drawing. The views required will vary, sometimes one view is sufficient, while in other cases two or three views of a part may be required.

Assembly Drawing. An assembly drawing will show all the parts put together in their proper places showing the function and location of each part. It is not usual to dimension an assembly drawing. Occasionally principal dimensions are shown, also main centre dimensions. Reference numbers are placed on an assembly drawing which correspond to the reference numbers on the detail drawings; this enables one to quickly locate each part in the assembly and understand its function.

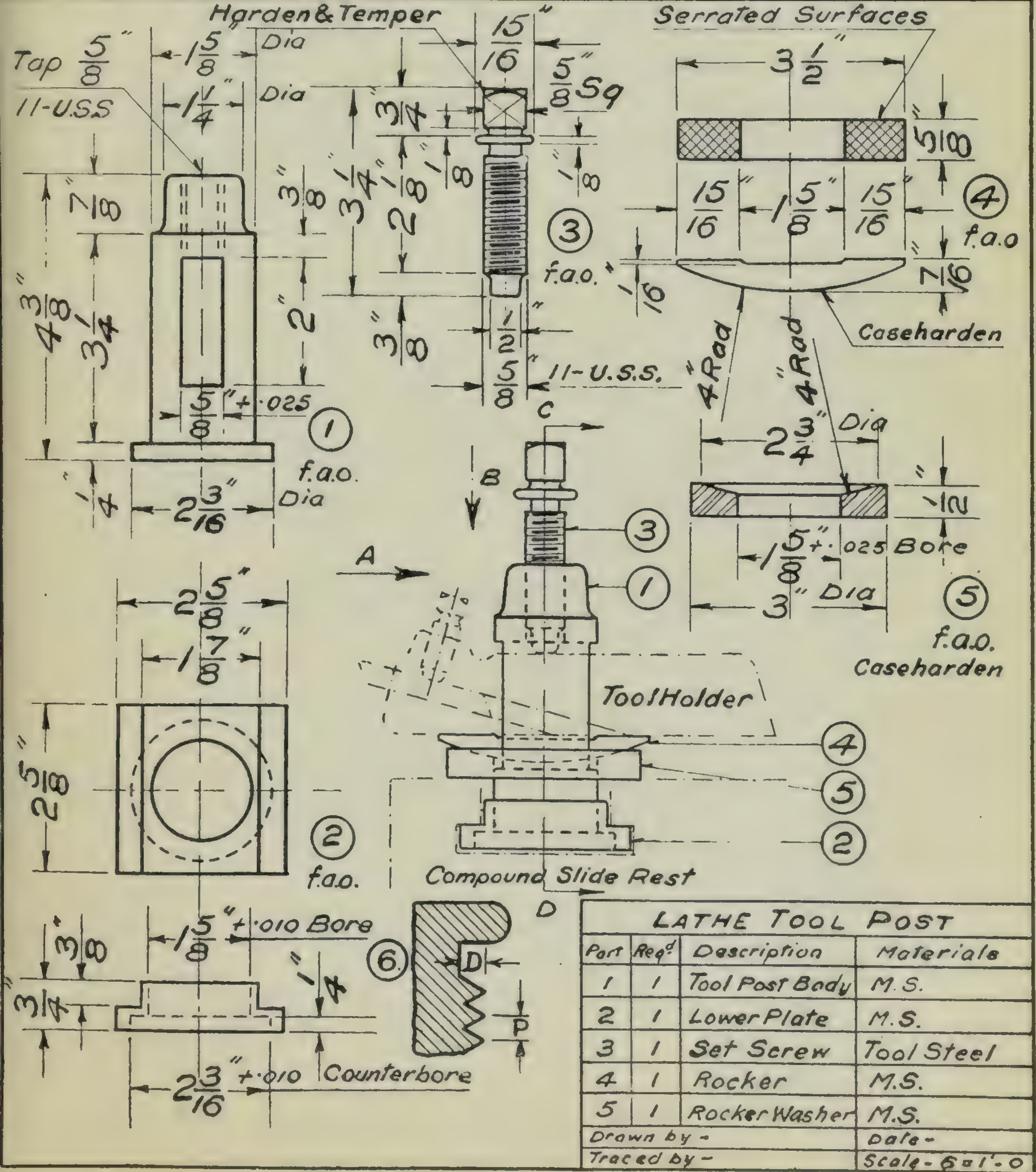
Reference Numbers. The part number or reference number on the detail and assembly drawing is usually enclosed by a circle. This method prevents the figures used being mistaken for dimensions.

Quantity of Parts Required. Sometimes one drawing of a part may be shown, but several of the parts may be required in the assembly. The number of pieces required is usually stated in the title at the bottom of the drawing. On some drawings the number of a particular part is specified adjacent to the reference number. **Example,** (3) 1 req'd (one required).

Heat Treatment Notations. The set screw, part number 3, is made of tool steel. It is therefore necessary to place a notation as shown. "Harden and Temper." This treatment is necessary to prevent the end of the screw from "burring" after continual use. The temper required will be left to the judgment of the experienced workman. The rocker, part number 4, would be case-hardened to give it a tough core and a hard wearing case.

Spacing the Views. Before starting to draw any details, it is necessary to space your views to prevent crowding in any part of the drawing. Keep in mind that some details are surrounded by more dimensions and notations than others, so that sufficient space must be allowed to prevent dimensions of one part conflicting with those of another part.

LATHE TOOL POST



LATHE TOOL POST

Part	Req^d	Description	Materials
1	1	Tool Post Body	M.S.
2	1	Lower Plate	M.S.
3	1	Set Screw	Tool Steel
4	1	Rocker	M.S.
5	1	Rocker Washer	M.S.
Drawn by -			Date -
Traced by -			Scale - 6"=1'-0

Thread Clearance. To obtain the neck diameter of the set screw shown in diagram 3, study the enlarged section shown in diagram 6. The depth of the thread clearance (D) is made equal to the "pitch" (P) of the thread, that is in this instance 1/11 of an inch. This rule applies to all cases when clearance is made for a thread which is cut to a shoulder.

Dimension Spacing. It is advisable to decide upon a definite space between dimension lines and to keep this space uniform throughout the drawings. Small dimensions are placed nearer to the drawing than the larger dimensions.

Notation for Square Shank (Diagram 3). One view only is shown of this screw, therefore it is necessary to indicate by notation that the top end of the screw is squared (⅝″ sq.). Sometimes diagonal lines on the flat face are used to show a square shank.

Exercises—

1. On a 9″x12″ piece of drawing paper make a detail drawing of parts 1 to 5. Leave out the assembly and rearrange drawings to uniform spacing. Scale, half full size.

2. On another sheet of paper draw a sectional elevation on line (CD), looking in direction of arrow (A) on the assembly drawing, and add a plan looking in direction of the arrow (B). Scale, full size.

NOTE. Do not represent the toolholder in plan, but show it in section. Size of toolholder in section ½″x1¼″. Do not show compound slide in plan or sectional elevation.

FREEHAND SKETCHES OF SCREW AND BOLT FASTENINGS

You have already sketched freehand, screw fastenings that are commonly used. In this lesson you will find the sketching a little more difficult. The fastenings shown on this diagram sheet are a few of those used for special fastening involving other materials than iron and steel.

The Stove Bolt, Diagram 1. As its name suggests it is used for fastening parts of stoves together. If you examine your own stove you will see that this bolt is used for fastening the mild steel sheet to the heavier cast iron parts.

The Toggle Bolt, Diagram 2. This fastening is used to fasten wood or metal to hollow brick, or tile, which is inaccessible at the back. The back piece, which is loose riveted to the screw, has a U shape section as shown. A hole is made in the brick or tile large enough to pass the U shaped piece through while it is laying close to the screw. When it passes through the hole it swings vertical, because one side is longer and consequently heavier than the other. The wood is then put over the screw and the work is bolted securely to the tile or brick.

The Drive Screw, Diagram 3. These hardened metallic drive screws are used for permanent fastenings to be made to iron, brass and aluminum castings. They may also be used on steel, Bakelite, etc. Their use speeds up production in assembling parts in many industries, and in many cases they have taken the place of machine screws, escutcheon pins, etc. Other screws in this class are self-tapping hardened and threaded screws, which are turned into the drilled or punched holes in metal with a screwdriver.

The Rag Bolt, Diagram 4. This is a forged bolt with a rectangular section tapering off until it meets the round part where the thread is cut. The edges are cut when hot to give it the ragged effect, so that it will grip into the lead, which is poured into the hole with the bolt in position. A hole is cut into stone or concrete larger than the end of the bolt and tapered or undercut to cause the lead to lock into the stone. This is one of many types of foundation bolts and is suitable for holding down light machines without much vibration. The disadvantage in using this type of bolt is that it cannot be removed without destroying the stone or concrete.

The Expansion Bolt, Diagram 5. A lag screw is used to thread into a malleable cast shield which pivots about the upper grip which holds the two parts of the shield together. As the tapered screw enters the shield, the lower end moves outwards and binds into the sides of the hole previously drilled. It is used to fasten articles to stone, marble, brick, slate or concrete.

The Lewis Bolt, Diagram 6. The shank of this bolt is rectangular in section with one side parallel to the axis of the bolt. The hole is undercut in the stone on one side to suit the taper side of the bolt. The bolt is placed in the hole and the key is placed against the parallel side. The machine is then placed over the bolt. As the nut is tightened the bolt lifts against the tapered side of the hole and is locked securely. The hole is made deeper than the bolt to give the clearance, so that it can be easily removed.

Expansion Bolt, Diagram 7. This is a new type of foundation bolt and can be used in a round hole with parallel sides. As the bolt is turned the lower elliptical tapered nut is drawn towards the head of the bolt until it meets the resistance provided by a distance piece made from a piece of pipe. The two tapered cast pieces are then drawn towards each other, and in doing so their tapered faces force the encasing split shield outwards. As the shield expands, it grips the sides of the hole giving tremendous gripping power. The split shield is held together with 2 coils of wire as shown in the diagram.

The Lag Screw, Diagram 8. This screw is sometimes called a "coach screw," and is used to fasten metal to wood, or wood to wood. The screw is tapered and has sharp threads to bite its way into the grain of the wood.

The Hanger Bolt, Diagram 9. This bolt is used to fasten hangers to wooden supports to carry line shafting. The hanger may be removed by unfastening the nut, leaving the bolt in place.

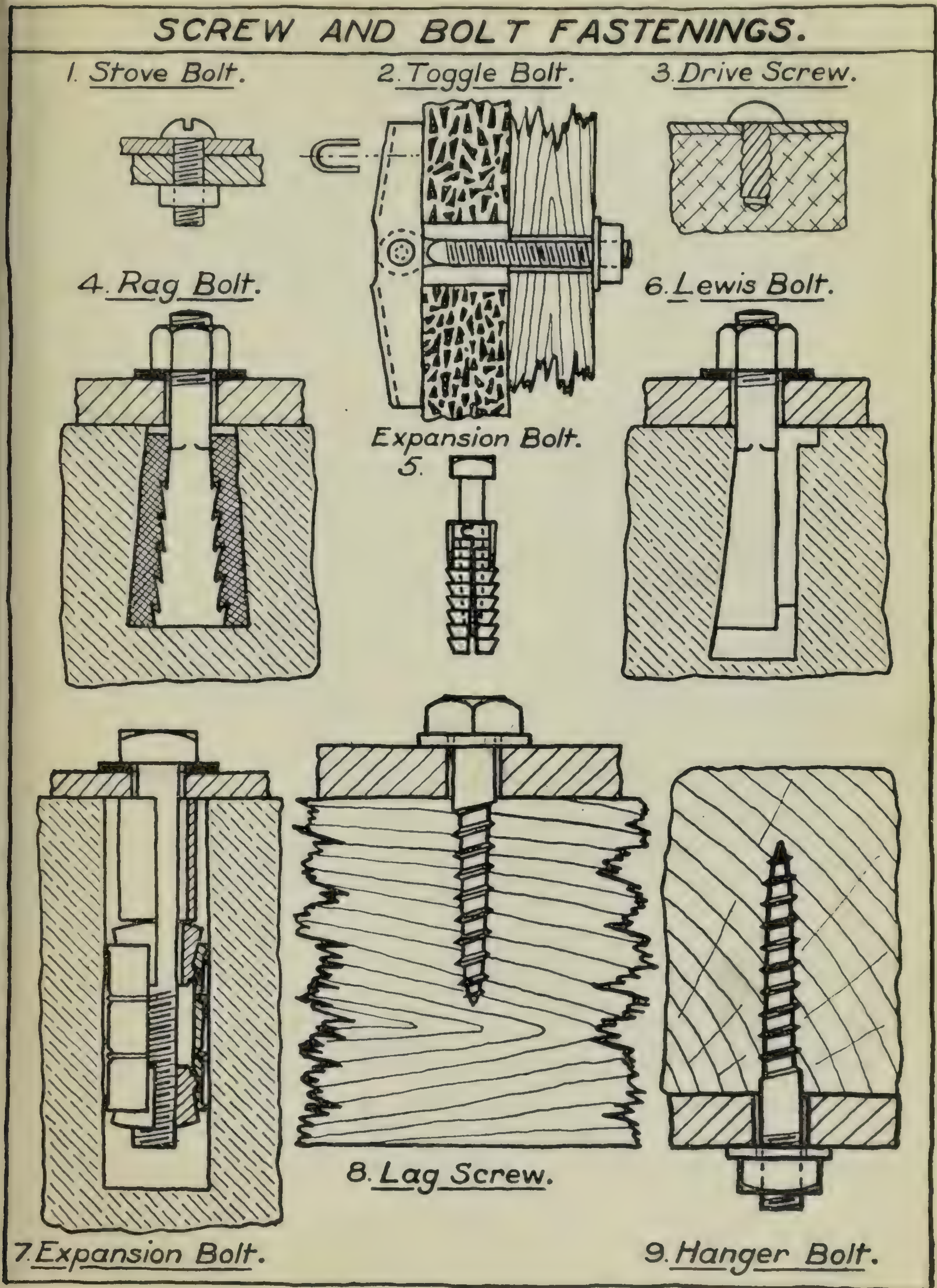
Dowell Pins. These are an accessory to machine fastenings. They are made parallel or tapered with a precision fit into reamed holes. They function as accurate position locating devices as follows:

1. To re-locate detached parts.

2. To maintain alignment of assembled parts. Dowell pins are used frequently in machine tool assembly (see page 119).

Note. Finished machine bolts in closely fitted holes are used to function as locaters.

Exercise: On a 9″x12″ piece of drawing paper sketch the fastenings shown in the diagrams. Approximate the sizes and arrange your work to suitably fit the sheet. Use only an HB pencil.



Freehand Sketches

DRAWING SCREW THREADS WITH HELICAL LINES

You are already familiar with methods of representing threads by straight lines and the sectional shapes of Square, U.S.S. and Acme threads. It is much quicker to draw threads with straight lines. As a general rule threads on a screw, 1″ diameter or less, are drawn with straight lines. Large diameter screws are represented by helical lines and it is the purpose of this lesson to show how this may be accomplished. The "Lead" of a thread is the amount of progression into a nut, per revolution of the screw. The "Pitch" of a thread is the distance from the top of one thread to the top of the next thread.

Note: In single threads, as in diagrams 5 and 8, "Pitch" and "Lead" are equal. In the double thread, diagram 12, the "Lead" equals twice the "Pitch."

To Draw a Square Spring, Diagram 3. The outside diameter of the spring is 1½″, the inside diameter 1″, and the "Lead" 1″. First proceed to lay out the helical lines shown in diagrams 1 and 2, and then transfer them to the drawing in diagram 3.

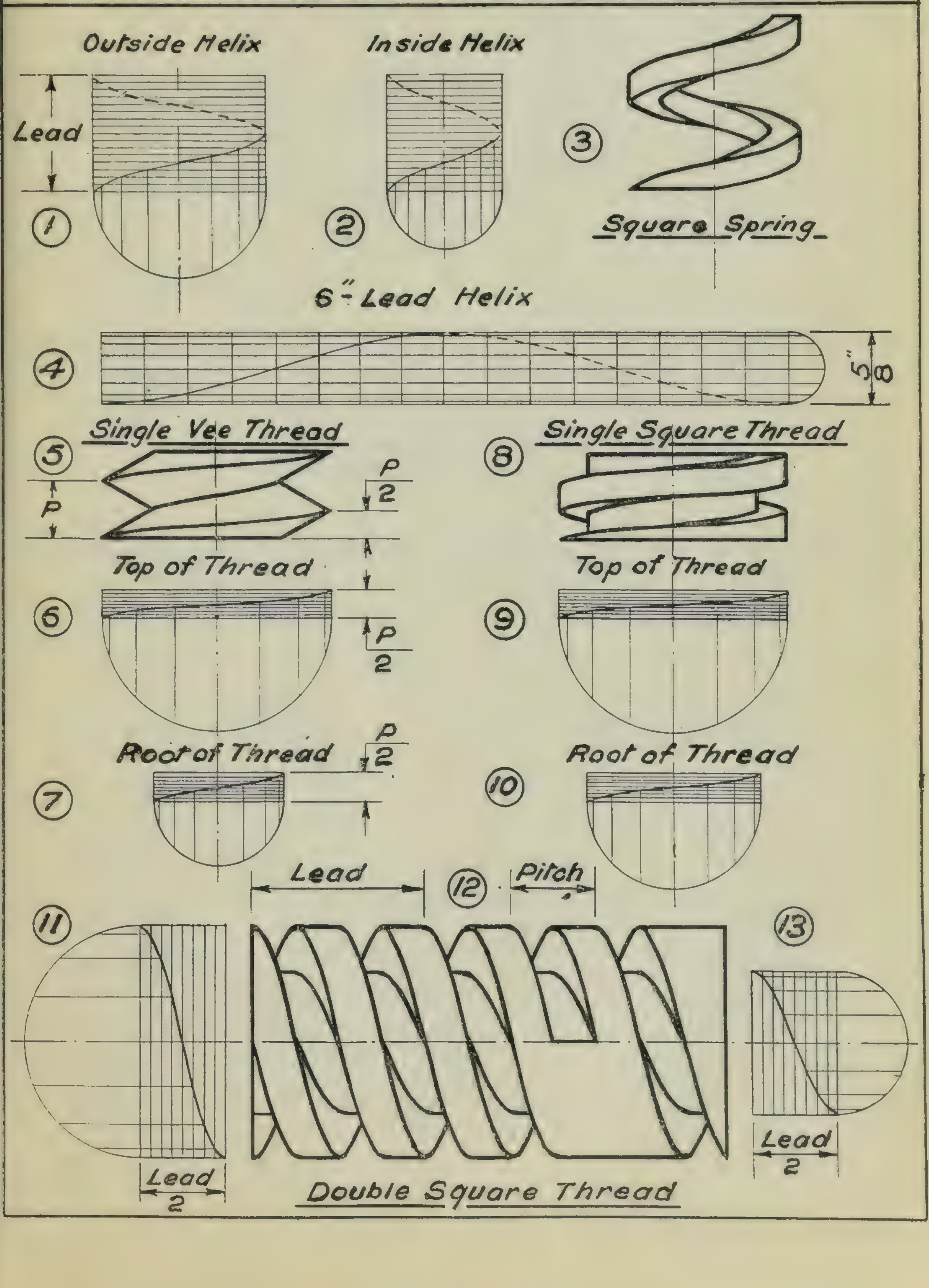
To Lay Out a Helical Line, Diagram 1. Divide the "Lead" of the helix into any even number of parts, such as 16 in diagram 1. Draw a semicircle as shown and divide the circumference into the same number of parts as the "Lead," in this case 16. The semicircle having one-half the circumference will be divided into 8 equal parts as shown. Project the divisions of the circle to the corresponding divisions of the "Lead" in their order, as shown in diagram 1. From the intersection of these lines, draw the helix so obtained. This method applies to diagrams 2, 4 and others shown.

To Make a Helical Template. Take a piece of celluloid and place it over the drawing of the helical line. Trace the path of the helix on the transparent celluloid with a sharp scriber. Cut away the celluloid at the ends and snap the celluloid with the fingers. If the helical line is cut deep with the scriber, it will break off clean. Smooth the edge with a file or abrasive cloth and check again to the drawing. The template can be used directly on to the drawing, to guide the pencil to duplicate the helical line. For ink drawing, place a thin set square beneath the template to prevent the template from drawing ink from the pen and spoiling the tracing (see page 94).

Drawing a Single Vee Thread, Diagrams 5, 6 and 7. The outside diameter is 2″ and the "Pitch" ½″. Draw the angle of the thread at 60° to obtain the root diameter and then proceed as already explained.

Drawing a U.S.S. thread with helical lines, is similar to the V thread, except that there will be two similar helical lines for the flat at the root and two similar helical lines for the flat at the top or crest of the thread, similar to square thread in diagram 8.

SCREW THREADS WITH HELICAL LINES



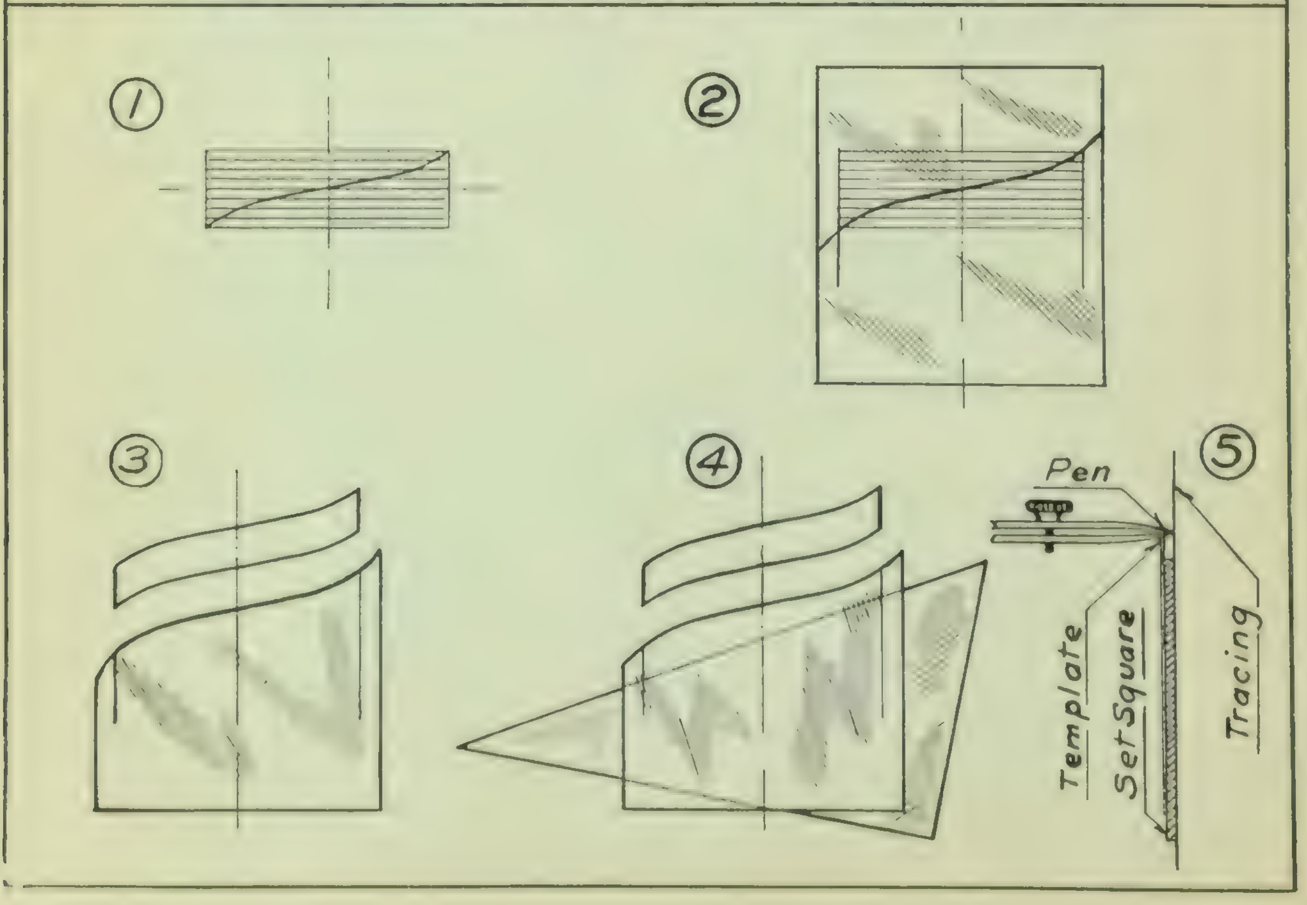
Drawing a Single Square Thread with helical lines as shown in diagrams 8, 9 and 10. Outside diameter 2″, "Pitch" ½″. The same template, diagram 9, is used for both edges of the top of the thread, similarly the template, diagram 10, is used for both corners at the bottom of the thread.

Drawing a Double Square Thread. Diagrams 11, 12 and 13 show how to lay out helical lines for a double thread. One thread groove is terminated short of the other groove, to show clearly that there are two separate threads. The screw is 2″ outside diameter, the "Lead" is 1½″ and the "Pitch" ¾″, so that the depth of thread would be P/2 or ⅜″, giving a root diameter of 1¼″.

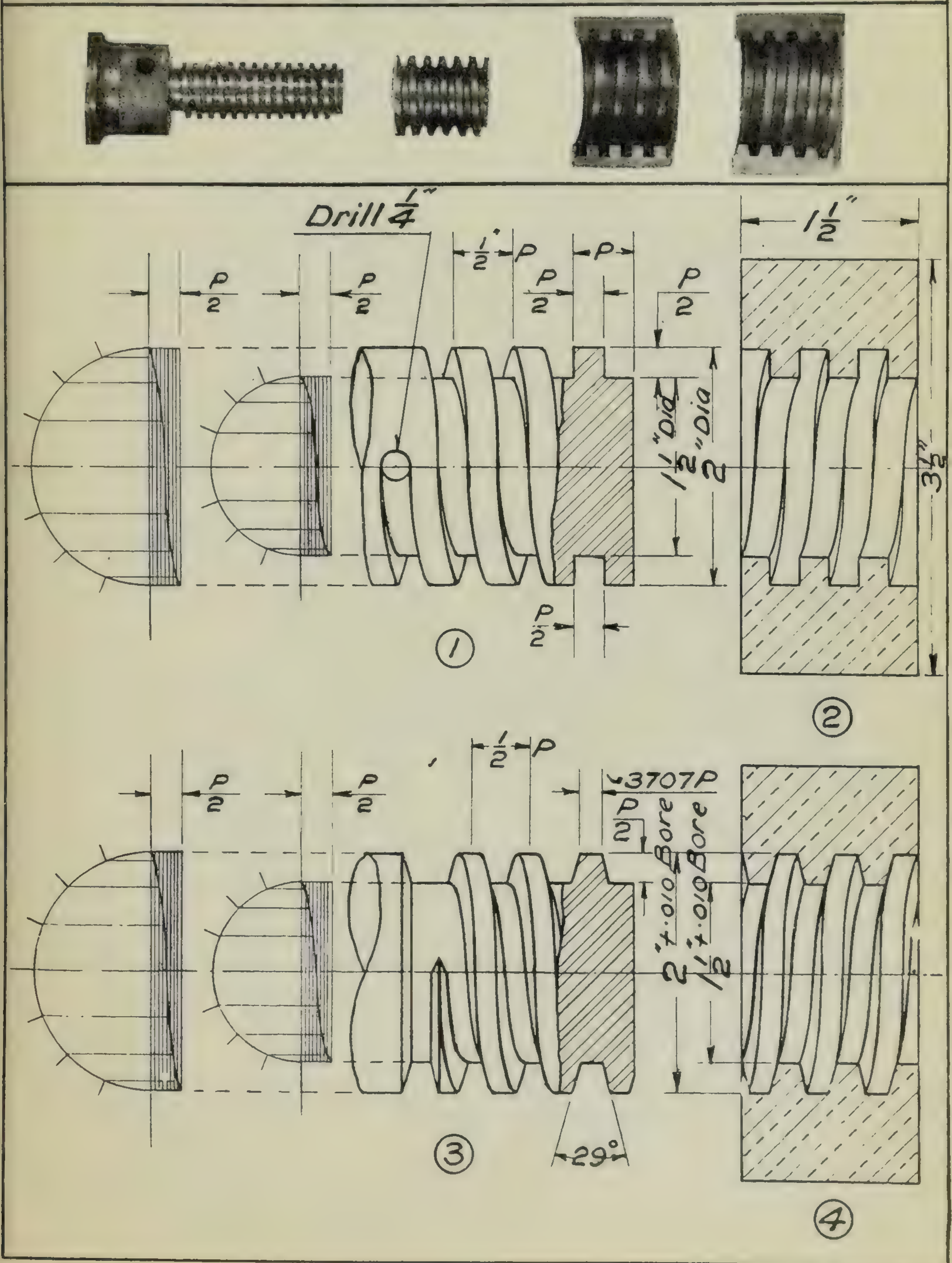
Exercises:

1. Draw on a 9″x12″ piece of paper, the diagrams as shown, but replace diagram 5 with a drawing of a U.S.S. thread. Do not put in any dimensions.
2. Draw the external and internal Square and Acme threads with dimensions. Scale full size (page 95).

USE OF CELLULOID TEMPLATE



EXTERNAL & INTERNAL SQUARE & ACME THREADS



PIPE JOINTS

Various types of pipe joints may be used depending upon the nature of the liquid or gas being conveyed, the pressure in the pipes and the accessibility of the pipe joint.

Diagrams 1 to 7 show pipe ends threaded into various fittings to make joints that are used mostly for low and medium pressures.

Diagrams 8 to 13 show types of pipe joints where the body of the pipe is not threaded, other methods of making a joint being adopted.

Nipple and flange joint, Diagram 1. The nipple shown at (B) is threaded with a standard pipe thread, which has a taper of ¾" per ft., or 1/16" per inch. The flange (A) is tapped with a pipe thread also tapered ¾" per ft. so that when the nipple is threaded tightly into the flange it makes a tight sealed joint. (See section of a pipe thread in the tables provided on page 99.)

Coupling joint. Diagram 2 shows two lengths of pipe joined together with a common coupling, which has tapered internal threads from both ends to receive the pipe.

Sealing pipe joints. Various plastic compounds are sold for putting on pipe threads to seal the joint. Good results may be obtained by using white or red lead. Such a substance also prevents the metals from seizing under heavy pressure when screwed together tightly.

A flanged union joint is shown in diagram 4, which is a section of a joint where the two lengths of pipe are screwed into companion flanges (D) which are joined together with bolts. A packing ring or gasket (E) is held between the inside faces of the flanges so that when they are bolted together the resilient gasket makes a sealed joint.

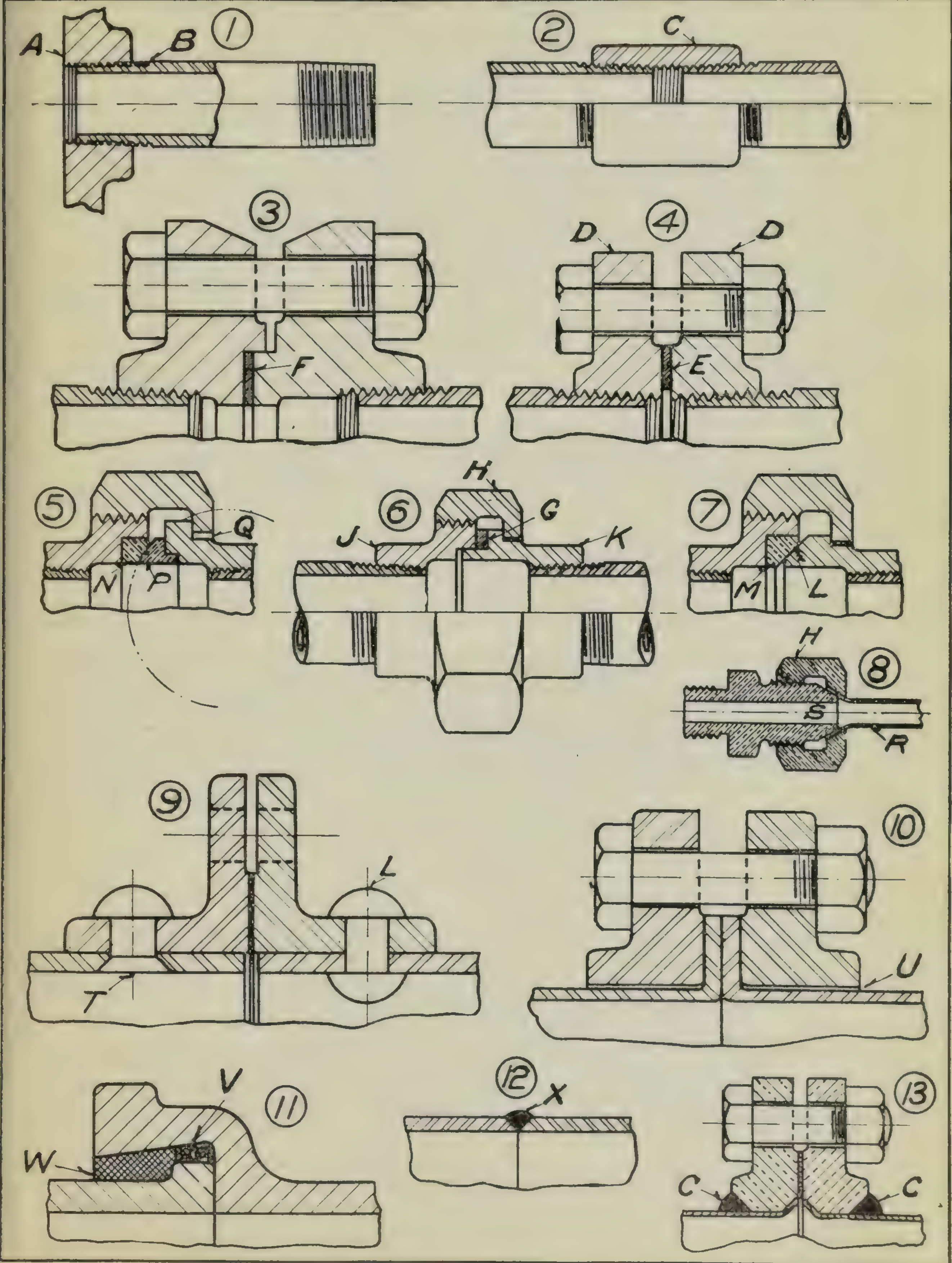
A Spigoted flanged union is shown in diagram 3; the spigot and recess of this joint prevent any possibility of the gasket (F) being blown out under pressure. This type is used mostly for ammonia and hydraulic joints. For hydraulic work an extra heavy pipe wall is used.

A Common union joint is shown in diagram 6 with a gasket (G) under pressure from the nut (H) drawing the screw parts (J) and (K) together.

A Metal Seat union joint is shown in diagram 7. No gasket is required in this joint, the part (L) has a bevelled machined surface in contact with a bronze inserted seating (M), giving a tight joint with a metal to metal contact.

A Spherical Metal Seat union joint is shown in diagram 5. This joint has two bronze inserts (N) and (P) which permit a limited degree of misalignment of the pipe. Note the clearance at (Q).

PIPE JOINTS



A Conical Metal union is shown in diagram 8. This joint is used for connecting small copper pipe, such as is used in automotive feed lines and oil pipes. The end of the pipe (R) is flared out to fit over the conical end (S), the parts are drawn together tightly with the union nut (H).

A riveted and bolted flange joint is shown in diagram 9. This joint is used for large sized pipe. The flanges are angle shape in section and are riveted to the pipe and then the flanges are drawn together with bolts. A countersunk rivet, shown at (T), is shown in contrast with a cup head rivet protruding inside the pipe. This cup head rivet would be objectionable for use in dredging, or where the substance conveyed was not fluid.

A High Pressure joint is shown in diagram 10 with the ends of the pipe flanged over and pressed together with bolted flanges which are free to slide on the outside of the pipe. Note the clearance at (U).

A Cast Iron Pipe joint is shown in diagram 11 and is used for water and gas mains. Oakum is first caulked into the joint at (V), and then molten lead is poured in, which is followed by further caulking at (W).

A Welded Pipe joint is shown in diagram 12. The steel pipe is welded as shown at (X) making the two connected pipes one homogeneous whole.

A Brazed joint is shown in diagram 13. This is largely used for copper piping on marine work when bronze flanges are used to bolt the pipe together. The brazing is shown at (C). Copper is used on ships owing to its ductility, making it suitable to resist the heavy strains to the hull during storms.

Exercises.

1. On a 9″ x 12″ piece of paper sketch freehand and arrange the diagrams shown from 1 to 7 and name each joint.

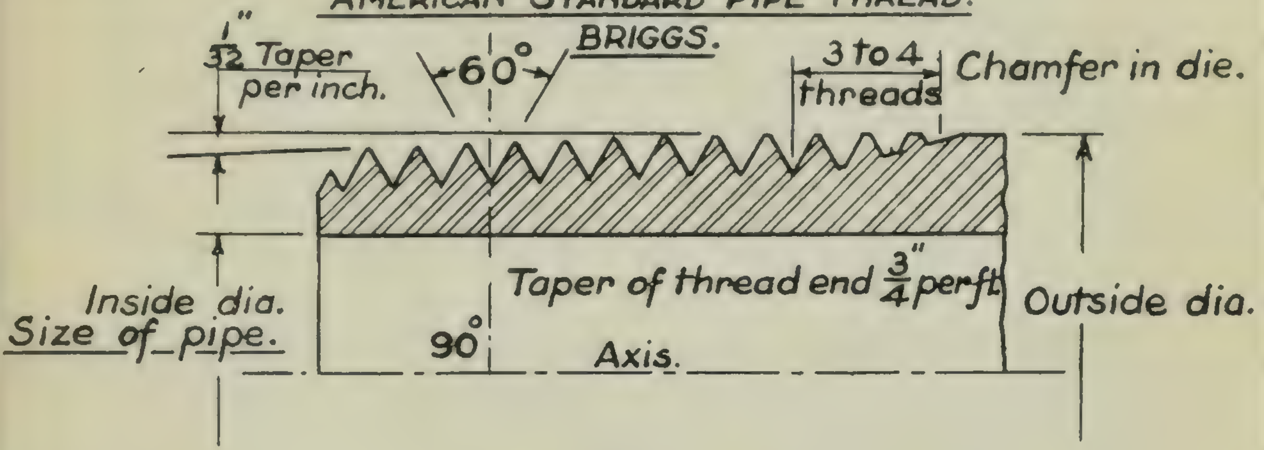
2. On a 9″ x 12″ piece of paper sketch freehand and arrange the diagrams shown from 8 to 13 and name each joint.

3. On a 9″ x 12″ piece of paper draw two enlarged sections of two pipe threads; (a) Briggs, (b) Whitworth.

PIPE THREADS.

AMERICAN STANDARD PIPE THREAD.

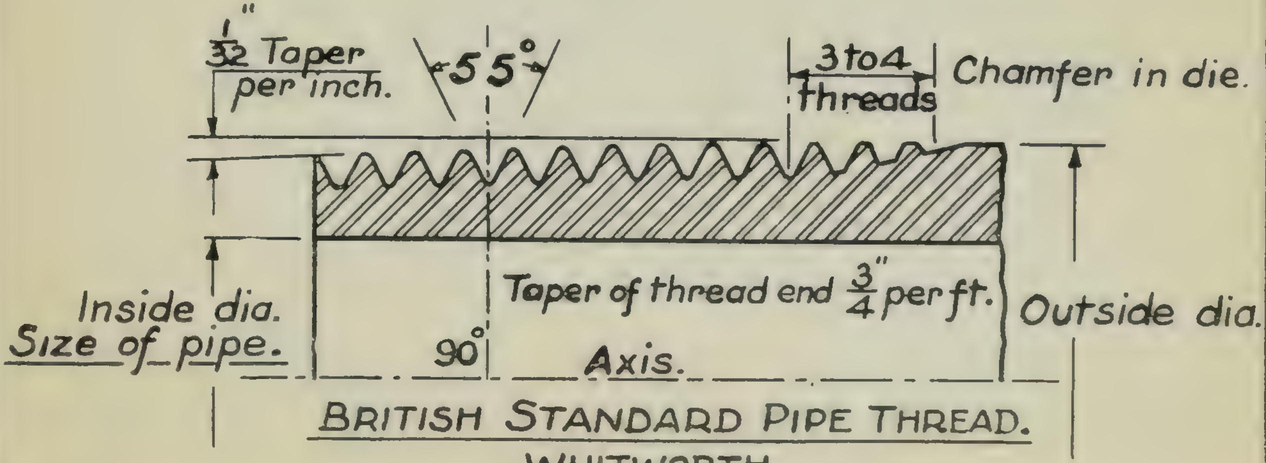
BRIGGS.



TAP DRILLS FOR PIPE TAPS

Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps	Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps	Size of Tap	Drills for Briggs Pipe Taps	Drills for Whitworth Pipe Taps
⅛	21/64	5/16	1¼	1 15/32	1 15/32	3¼	....	3½
¼	29/64	27/64	1½	1 23/32	1 25/32	3½	3 13/16	3¾
⅜	19/32	9/16	1¾	....	1 15/16	3¾	....	4
½	23/32	11/16	2	2 3/16	2 5/32	4	4 3/16	4¼
⅝	......	25/32	2¼	....	2 13/32	4½	4 11/16	4¾
¾	15/16	29/32	2½	2 11/16	2 25/32	5	5¼	5¼
⅞	....	1 1/16	2¾	....	3 1/32	5½	....	5¾
1	1 3/16	1⅛	3	3 5/16	3 9/32	6	6 5/16	6¼

SIZE	⅛	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4½	5	5½	6
THREADS (Briggs)	27	18	18	14	—	14	—	11½	11½	11½	—	11½	—	8	—	8	—	8	—	8	8	8	—	8
THREADS (Whitworth)	28	19	19	14	14	14	14	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11



BRITISH STANDARD PIPE THREAD.

WHITWORTH.

KEYS AND SHAFTS

The purpose of this lesson is first, to make you familiar with some of the various methods of keying work to shafts, and second, to give you an opportunity of drawing to scale from written instruction and data.

Because of the objectives above mentioned you will observe that the adjoining diagrams do not give any dimensions or notation other than the name of each form of fastening.

All shafts with the exception of diagram 12 are 1¼″ diameter, and the parts keyed to the shafts with the exception of diagrams 5 and 12 are 2″ diameter.

Dimensions of Keys. These are best obtained from the tables of a data book. Key proportions vary in relation to the diameter of the shaft.

Square keys, shown in diagrams 3, 7 and 8, are usually made equal to one-quarter of the shaft diameter. In the diagrams mentioned the shaft diameter is 1¼″ so that the key width and thickness would be ¼ x 1¼″=5/16″.

Gib key, shown in diagram 5, width=¼ times diameter of shaft up to 6″. Greatest height of the tapered part equals 1/6 times diameter of shaft up to 6″. Length=length of hub+½″. Height of head approximately equals the width.

Taper of a key. The taper of sunk keys is usually made ⅛″ per foot or 1 in 96; this may be increased in some cases to 3/16″ per foot.

The depth of a taper keyseat in the hub at the deep end shown in diagram 5 should be 3/5 of the key thickness.

Types of keys — Saddle key (Diagram 1) is made concave on one side to fit the shaft, and it is tapered on the top. It should fit easy on the sides and tight on the top and bottom. This is not a positive drive and therefore is only suitable for very light loads.

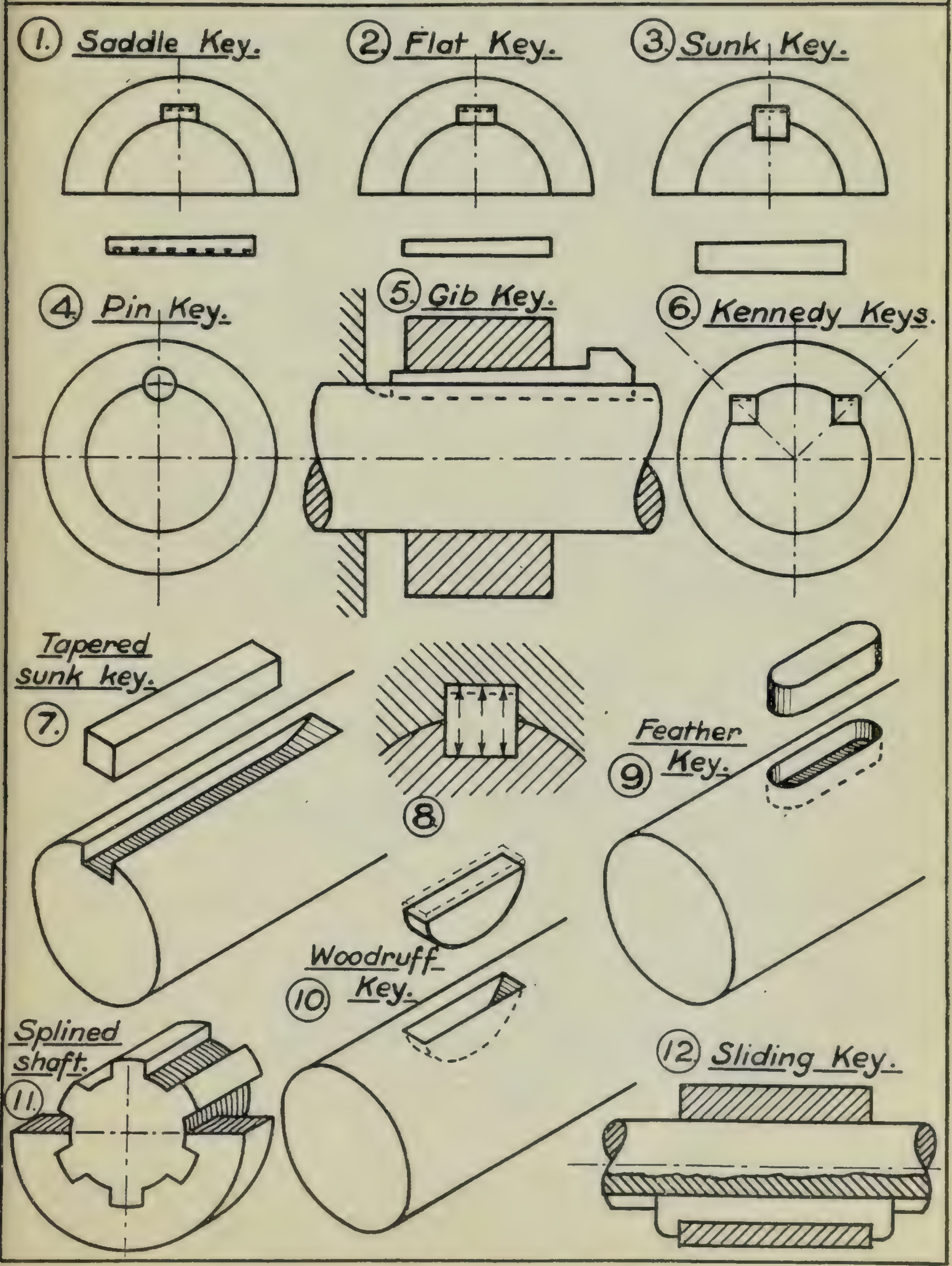
Flat key (Diagram 2) bears against a flat on the shaft and fits similar to a saddle key, except that it is slightly more positive.

Tapered sunk key (Diagrams 3 and 7). This key gives a positive drive and the taper fit prevents end movement of the hub on the shaft. It should have a bearing on both parallel sides.

Straight sunk key, such as the **Feather key** (Diagram 9) should have a tight fit on the sides and a slight clearance or light bearing on the top.

Pin key (Diagram 4). A hole is drilled parallel to the axis where the hub meets the shaft, and a round pin driven in to key them together. Sometimes with light loads the hole is tapped and a grub screw is used in place of a tightly driven pin. Diameter of each is usually ¼ of the shaft diameter.

KEYS AND SHAFTS.



Fit of a tapered key is shown in diagram 8. As the key is driven in, forces are exerted on the hub and shaft as shown by the arrows. This tends to exert pressure between the hub and shaft on the side opposite to the key. The corners of keys should be slightly rounded with a file before being driven in, to prevent the corners interfering with the required bearing on the flat sides of the key. Two keys are used sometimes at 90° positions, never 180°.

Kennedy keys (Diagram 6). This double key system is used for heavy loads on shafts usually over 6″ in diameter. When the torque or twisting action is intermittant and the direction of rotation of a shaft frequently reversed, this double key system is desirable.

The keys are located on centre lines shown at 45° to the horizontal, so that diagonal lines drawn through the corners of the keys intersect at the axis of the shaft. The keys are square at the small end, the width of the key is 1/5 to 1/6 the diameter of the shaft. The taper is ⅛″ per foot. The keys are driven in from opposite sides of the hub, and under load are in compression instead of being subjected to shearing stress as with an ordinary key.

Feather key (Diagram 9). This key is round at both ends, and is usually made 0.001″ oversize in width to ensure a tight fit in the milled keyway in the shaft. The key shown is 1″ long, and is 5/16″ wide; height of key 15/32″, and depth of keyway 5/16″.

It is preferable to use 2 keys diametrically opposite on the shaft so that the hub can slide freely on the shaft with balanced key friction.

Sliding key (Diagram 12), such as is used on splined shafts of a lathe to turn the worm of the feed mechanism and allow the worm to slide freely along the shaft. Shaft ¾″ diameter, hub 1⅜″ diameter, length of hub 1⅝″, key ¼″ square.

Woodruff key (Diagram 10). These keys are made from slices cut off a round rod. The dotted lines show the half circle. This key is 1″ diameter and ¼″ thick. The keyseat is milled in the shaft with a Woodruff Milling Cutter to a depth of 5/16″, thus allowing the key to protrude above the shaft ⅛″. The keys are used considerably in building machine tools.

Splined shaft (Diagram 11). No separate keys are used. The keys are cut solid on the shaft and are usually 4, 6 or 8 in number. The hub is bored and broached to fit. One half the hub is removed on the drawing to show the splines. This form of fitting is used extensively in automobile transmissions.

Exercise.

On a 9″ x 12″ sheet of paper draw (scale full size) diagrams 1 to 6 and add end views of shaft and hubs for diagrams 9, 10, 11 and 12, according to information given in the lesson.

FLANGE COUPLING DETAILS

Couplings are used to connect lengths of shafting together. The photograph on the adjoining page shows a pair of cast iron flanges at A and the flanges fastened to shafts and bolted together at B. The bolts have minimum length of thread. There are many types of couplings used, the one illustrated here is one of the simplest types used. The protruding bolt heads and nuts may catch in the clothes of a workman causing serious injury. To prevent this possible danger, a rimed coupling shown on the lower part of page 105 is used. The rim of this coupling makes the outer edge wide enough to be used as a pulley if necessary.

Shaft alignment. This is provided for in the plain flange coupling by allowing one shaft to enter the opposite flange bore about ¼″. The flange coupling, with the rim, has a recess cut in one flange and a projection or spigot on the other made to fit to obtain shaft alignment. This spigot and recess could also be applied to a plain flange coupling.

Flange coupling assembly. This is illustrated on the upper part of page 105. The upper half of the drawing is in section, and the lower half in elevation. The keys are shown opposite in this drawing, but it is advisable not to have them opposite each other. This may be accomplished by turning the flange one-third of a revolution and bolting them together through the next hole in the flange.

A space of 1/16″ is allowed between the ends of the shafts to allow for clearance.

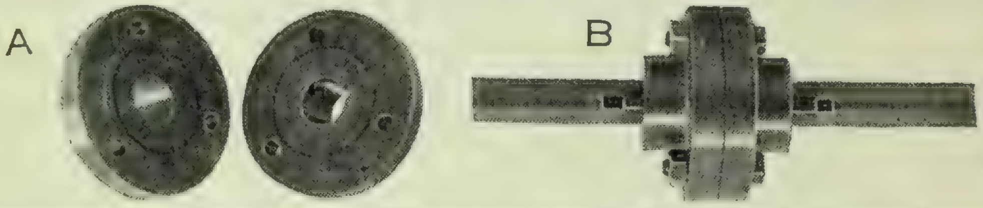
To assemble the coupling each flange is keyed to a shaft as shown in the assembly drawing, and then the flanges are bolted together. Faces of flanges are often machined after keys have been driven in to obtain true running with the shaft.

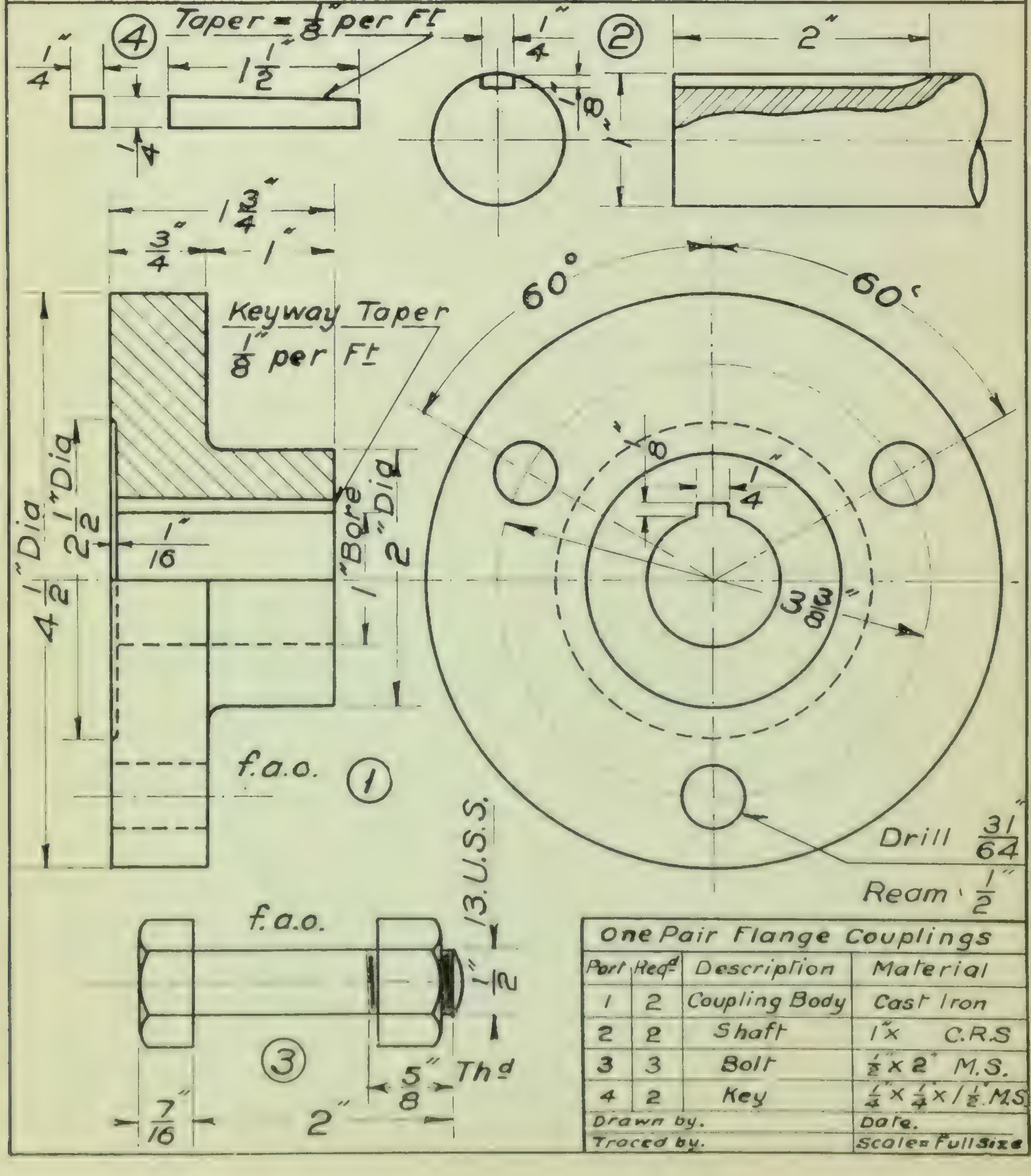
Exercises.

1. On a 9″ x 12″ piece of paper draw an end elevation of the plain flange coupling and an elevation with the upper half in section showing the keys NOT opposite each other. (Scale full size.)

2. On a 9″ x 12″ piece of paper draw an end elevation of the flange coupling with the rim shown in detail on the lower half of page 105. Add an elevation showing the upper half in section when the section plane cuts through the bolt holes. (Scale half full size.)

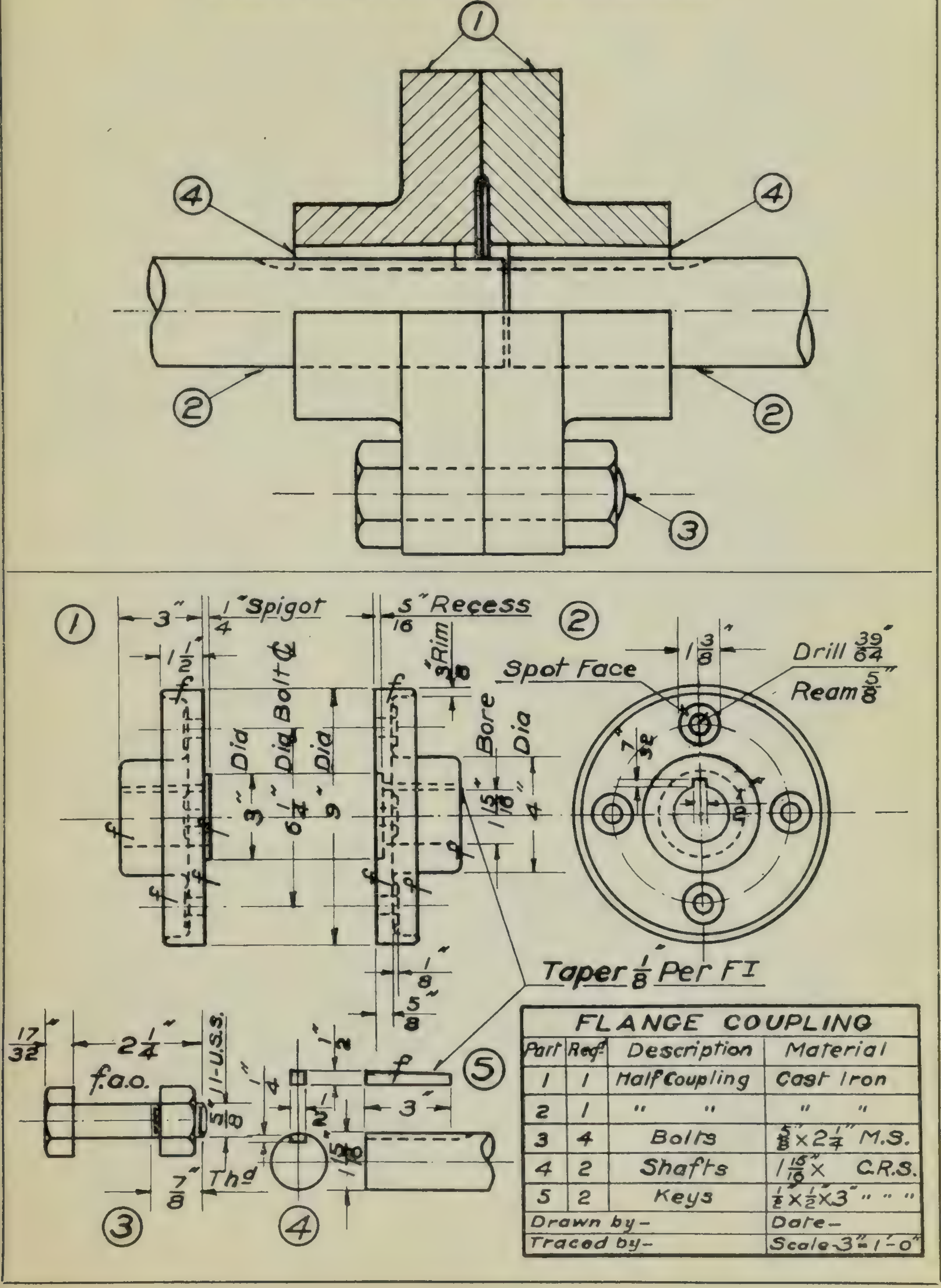
FLANGE COUPLING DETAILS





One Pair Flange Couplings			
Part	Req'd	Description	Material
1	2	Coupling Body	Cast Iron
2	2	Shaft	1" x C.R.S
3	3	Bolt	1/2" x 2" M.S.
4	2	Key	1/4" x 1/4" x 1 1/2" M.S.
Drawn by.			Date.
Traced by.			Scale= Full Size

FLANGE COUPLING ASSEMBLY



FLANGE COUPLING			
Part	Reqd.	Description	Material
1	1	Half Coupling	Cast Iron
2	1	" "	" "
3	4	Bolts	5/8" × 2 1/4" M.S.
4	2	Shafts	1 15/16" × C.R.S.
5	2	Keys	1/2" × 1/2" × 3" " " "
Drawn by–		Date–	
Traced by–		Scale 3" = 1'-0"	

TYPES OF LUBRICATORS

On the adjacent page are shown a few freehand sketches of the many types of lubricators which may be used. Lubrication and lubricating methods are of great importance in machine operation and has much to do with elimination of expensive repair bills and the length of time the equipment may be used.

Duties of a lubricant. Metal-to-metal contact of parts causes excessive wear, for without a lubricant friction is highest. To prevent wear there should be no metal-to-metal contact. A lubricant has two duties to perform, as follows:—

1. To act as a separator.
2. To prevent or reduce friction.

Use of grease. Grease is a good separator with a high film strength, but it is **not** a very good lubricant because it is not "slippery" enough. One distinct advantage of grease is that it does not leak.

Use of Oil. Oil provides "slipperiness", but in some cases does not have sufficient film strength to keep two pieces of metal apart. Selection of an oil for the kind of work it has to do is very important. In certain applications oil tends to leak out, so that arrangements must be made to prevent this loss. An oil film between metal parts acts like the sliding of a deck of cards with very slight resistance between the oil layers.

Greasing devices are shown as follows:—

1. **A common grease cup,** the grease being forced into the desired place by turning the screwed cap by hand.
2. **A grease cup with pin,** which is vibrated when a shaft (on which the point of the pin rests) is in motion; this action allows the grease to work through the space around the loosely fitted pin. When the rotation of the shaft ceases, the feed of lubricant stops.

Grease gun fittings are shown at (4), (6), and (9). These fittings are simple ball valves; the ball is kept to its seat to prevent escape of grease by a spring, and grease is forced through under pressure from a grease gun.

Oiling devices.

3. **A sight feed oiler.** The oil is contained in a glass reservoir and drips through the lower glass tube by operating the tap lever at the open position. The feed may be shut off when the lever is placed in the closed position.

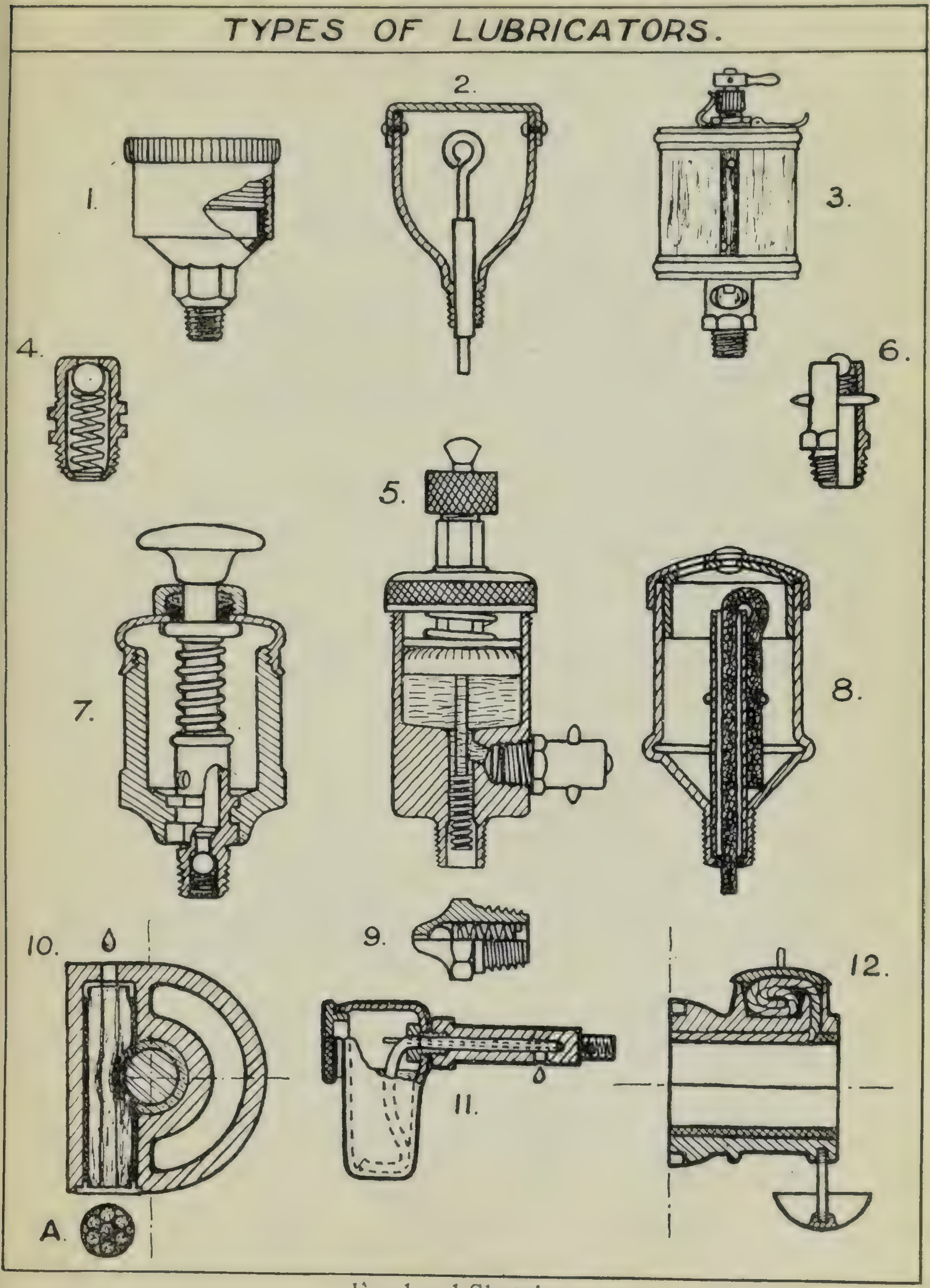
   (7) shows a section of a **pressure oiling lubricator** designed for individual application to chassis parts. It combines an oil reservoir with a spring-operated plunger pump. To give a bearing a supply of oil the plunger handle is pulled out and released, forcing oil with considerable pressure into the bearing.

4. **The "Gun-Fil" lubricator** gives continuous oil pressure feed to a bearing. It is filled with a standard pressure gun which compresses the spring which then re-acts, exerting pressure on the lubricant in the cylinder, forcing it around the threaded stem into the bearing. The amount of the threaded stem in the hole controls the rate of feed.

   Wick oilers are shown at (8), (11), and (12), providing a steady feed of clean oil to the desired bearing.

   A wool yarn lubricator is shown in diagram 10. This is one type as applied to a motor and functions to lubricate the bearing for a considerable length of time. The cylinder of wool strands at (A) fits into a hole alongside the bearing and the cut-away bushing allows the rotating shaft to press against the oil-soaked wool to receive a continuous spread of oil.

Exercise. On a 9" x 12" piece of paper sketch freehand the lubricators shown.



Freehand Sketches

SIMPLE TYPES OF CLUTCHES

A clutch is a connecting device used in transmitting power and may be divided into two types, the positive type and the friction type.

Positive Clutches. These are shown in diagrams 1 to 6, and are used as a transmission connection where slip is undesirable. They are used for comparatively slow speeds, and can only be engaged when at rest or in slow motion.

Friction Clutches. These are shown in diagrams 7 to 14, and are used for a wide range of loads and speeds where temporary slip or partial engagement is desirable, until both driver and driven members have attained the same speed. These resilient contact conditions are especially applicable where speed and power vary and intermittent engagement occurs.

Straight-toothed clutch or coupling. Diagram 1 shows an oblique view of one driving face of a three-jaw type. The two parts of the clutch are shown fitted together on the shafts in diagrams 2 and 3. The fixed half (2) is keyed fast to the shaft (4), and the loose half (3) is free to slide on the shaft (5) along a feather key fitted to the shaft.

Angular-toothed clutches. These are shown in two diagrams at (6). The one at (A) can drive in two directions, while the one at (B) can only drive in one direction.

Friction Clutches. These clutches drive through tapered surfaces being forced into contact. The angle of the taper varies from 4° to 10°, according to conditions.

Diagram 7 shows a cast iron tapered friction clutch with the outer part (A) in the form of a pulley acting as the sliding member and the inner part (B) keyed to the shaft.

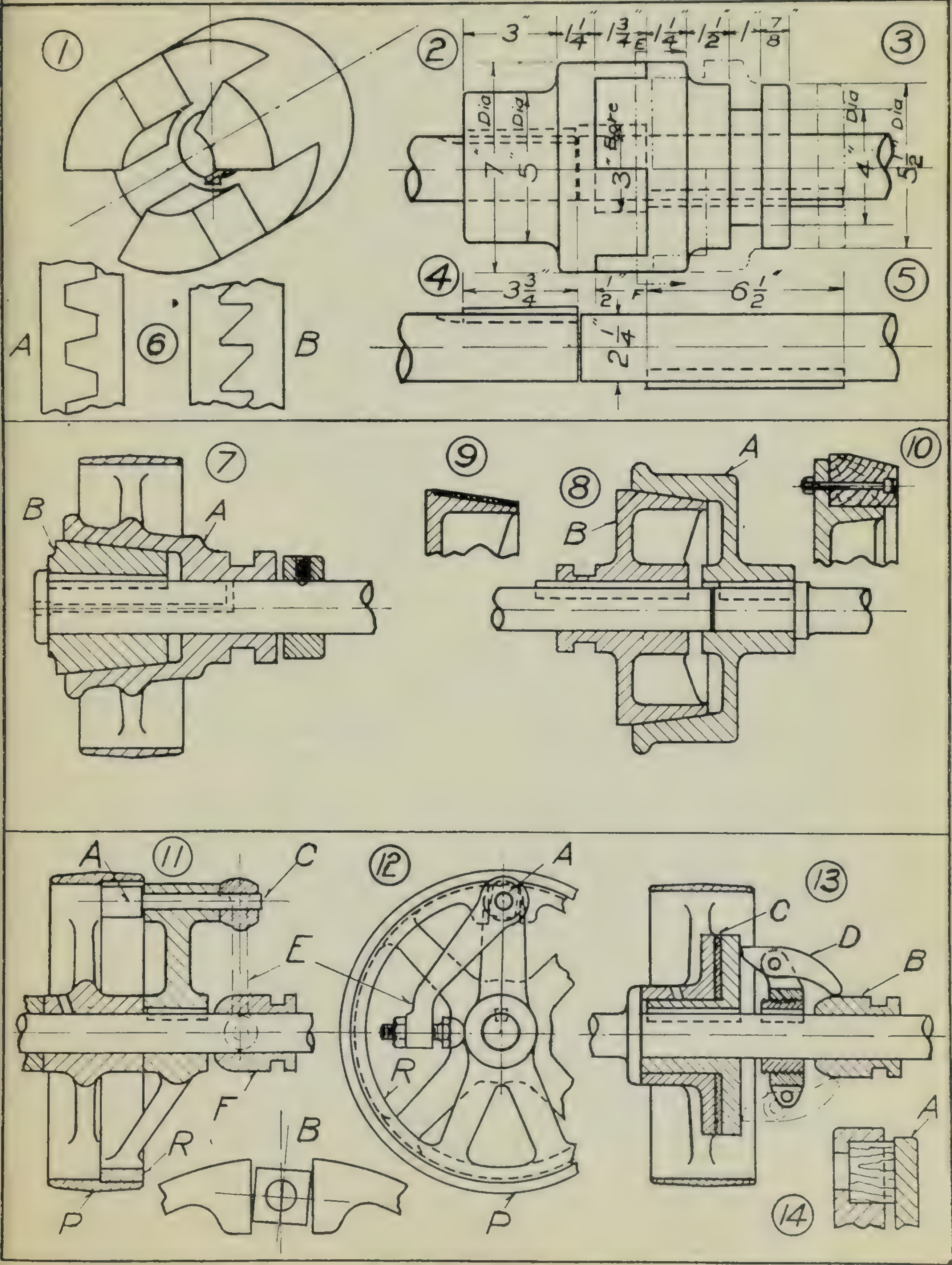
Diagram 8 shows another cast iron friction clutch with the outer part (A) keyed to the shaft, and the inner part (B) the sliding member.

A leather-faced friction clutch is shown in diagram 9. This leather-to-metal contact increases the coefficient of friction, and can be replaced when worn.

A wooden-faced friction clutch is shown in diagram 10. The wood and metal contact also increases the coefficient of friction, and can be replaced when worn.

The friction surfaces of a clutch may be either leather against iron, wood against iron, or bronze against iron. Some friction clutches have hardened tool-steel frictional parts to permit high pressures between the surfaces.

SIMPLE TYPES OF CLUTCHES



Radial expanding clutch. The type shown in diagrams 11 and 12 is frequently used in lathe countershafts for starting and stopping the lathe, and similar types of transmissions.

Diagram 11 shows a sectional elevation, and diagram 12 a part end elevation. The inner cast iron ring (R) is open at (A), diagrams 11 and 12, and the opening is shown enlarged at (B).

A rectangular head or cam fits loosely in this space and may be turned by the spindle (C) fastened to arm (E) which turns it. When the cone (F) is moved in by a shifter lever, the arm E is moved outward turning the cam (B) in the slot and expanding the inner ring (R) to give the friction drive against the outer pulley (P).

Friction disc clutch. This type of clutch may be single or multiple. A single disc type is shown in diagram 13. The surface of the pulley or the disc is surfaced with leather, fibre or hardwood —which can be removed when worn—and gives a high coefficient of friction. The pressure is exerted at (C) by sliding the cone (B), which lifts the three fingers (D), so that the opposite end presses the surfaces of the clutch tightly together. Pressure adjustment is provided by turning the threaded portion on the sleeve shown keyed to the shaft.

Diagram 14 shows a disc with renewable hardwood insert pins installed, with the end grain of the wood in contact with the face of the metal disc (A).

Exercises.

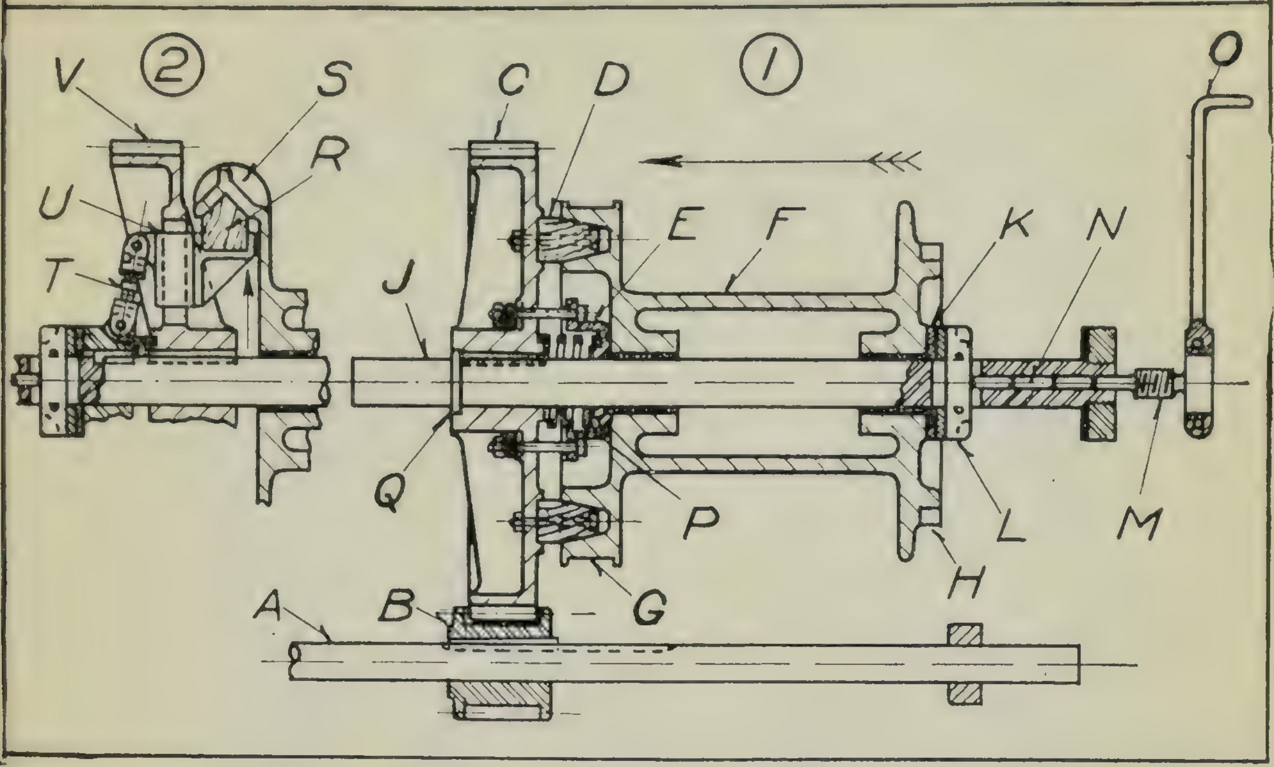
1. From the information given in clutch diagrams 1 to 5, draw on a 9″ x 12″ sheet of paper to a scale of 6″ = 1′—0″, a half sectional end elevation showing the left side of the centre line in section when cut on line EF. Draw also a front sectional elevation of the assembled clutch when cut with a vertical cutting plane through the centre.
2. On a 9″ x 12″ piece of paper, sketch freehand the contact method used in the various types of clutches you are familiar with.

Hoisting Drum Friction Clutch Assembly

Diagram 1 shows in section a type of friction clutch used with wire rope cables for hoisting loads on derricks, pile drivers and logging donkey operations. It is adopted when a slack line is intermittently used and consists primarily of a frictional drive between iron and hardwood surfaces.

The drive shaft (A) drives through a shrouded pinion (B) connected to a bull gear (C). The web of this gear carries a hardwood ring (D) and a spring yoke (E). The bushed cable drum (F) is provided with a band brake groove (G) and a ratchet and pawl at (H) to give a positive lock to the drum. The drum (F) when disengaged from the friction ring (D) is free to turn on the shaft (J). To drive drum (F) it is moved along shaft (J) in direction of the arrow. This engages the clutch by the conic recess of the drum engaging with the wooden ring (D).

HOISTING DRUM FRICTION CLUTCH ASSEMBLY



The pressure is applied to the clutch by pressure on thrust ring (K), exerted by turning the handle (O) which turns screw (M), fitted in a yoke on the outside of the bearing frame (not shown). The gib (L) and its washer are forced forward by turning screw (M) through pressure on followers (N), thus pressing the drum to engage at the clutch (D).

A heavy coil spring (P) separates the clutch surfaces to disengage the clutch when the pressure is released. The yoke (E) controls the spring extension. A collar (Q) on the shaft (J) resists the sliding tendency of gear (C) due to frictional thrust pressure.

Shaft (J) is not subject to torsional stress, the key securing gear (C) to the shaft (J) rotates the shaft in the bearings. The shaft area is reduced at the slot to admit the gib (L).

Diagram 2 shows another type of hardwood-to-iron frictional clutch. It is used for similar work to the clutch shown in diagram 1. This clutch shown in diagram 2 is an expanding type—the hardwood segment blocks (R) are forced outward into contact with drum (S). This action is accomplished by means of a toggle (T) and sliding block frames (U) which are guided in slots in the web of gear (V), the band brake in this case is installed on the other end of the drum (not shown). The advantage of this type of clutch is the absence of any side thrust.

Various synthetic substitutes have been produced giving a higher coefficient of friction than wood, but the replacement facilities in some cases are more favorable to hardwood.

FLEXIBLE COUPLINGS

Flexible couplings provide a movable or flexible element for connecting together two shafts which have their axis in the same straight line. Flexible couplings are chiefly used when making a direct drive from electric motors. A slight error in alignment of shafts in direct connected machines will create destructive strains on the shafts when operated at high speeds, and quickly wear out the bearings.

The Oldham coupling is illustrated with the freehand sketches at A, B, C and D. This coupling is suitable for slow speeds and heavy torques. It will take care of considerable errors of misalignment, either angular or offset. Sketches A, B and C show the various members of the coupling, and sketch D the assembly. A sectional elevation is shown in diagram 1, and an end elevation in diagram 2. Centre part of B is ½″ thick.

A rubber disc coupling is shown separated in diagrams 3, 4, 5 and 6. It is an ideal coupling for light duty up to 1¼″ shaft size. The flanges are die cast and the rubber disc has Tobin bronze bushings molded into place to receive the pins which are screwed into the recessed flanges. When assembled a clearance must be provided between the rubber disc and the flanges. The rubber disc can be removed and replaced by unscrewing the driving pins without disturbing either flange which is keyed to its shaft.

A rubber cushion flexible coupling is shown in diagrams 7 and 8. This coupling is suitable for medium and high speeds up to a maximum shaft size of 8″. This coupling owes its flexibility to pure rubber discs which fit into recesses in the flanges. The pins are of alloy steel, case-hardened and ground, and are fastened to the flanges with castle-nuts drawing the shoulders of the pins against the flanges. The rubber buffers are bushed with bronze bushes which are reamed to fit the ground pins.

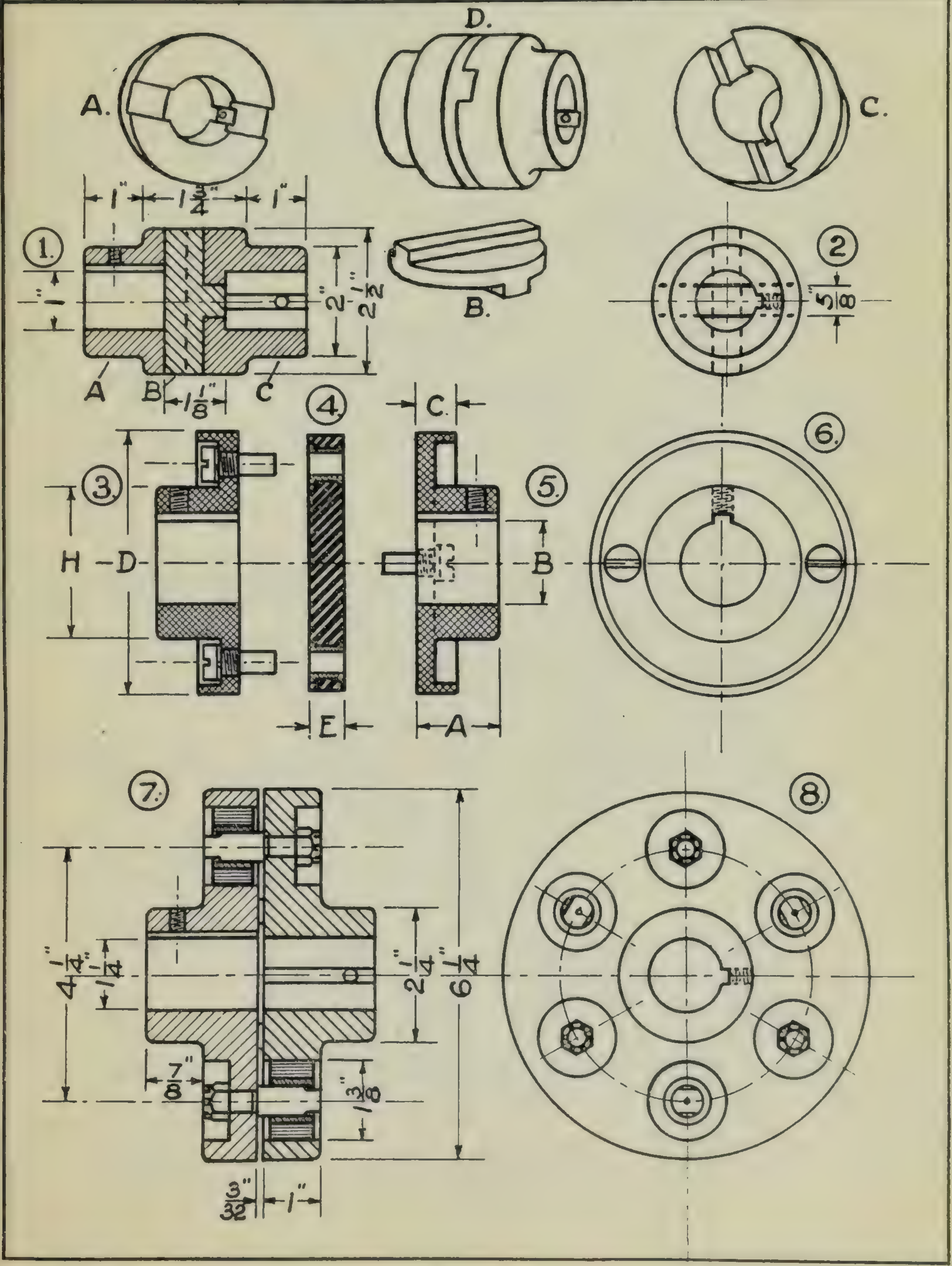
The bore of the flanges should be a tight fit on the shaft, and the key a tight fit on the sides of the keyway. A set screw is provided to hold the key in position.

The rubber cushion type of coupling gives flexibility and cushions all joints and vibrations. In addition to this the direction of rotation may be reversed without shock or clashing of pins. After years of service the rubber bushings can easily be replaced.

Exercises.

1. On a 9″ x 12″ piece of drawing paper draw two views of the Oldham coupling, diagram 1. Draw the upper half in section, and the lower half in elevation, and add diagram 2 an end elevation. Make these drawings with the axis of the shafts ¼″ out of horizontal alignment. (Scale full size.)

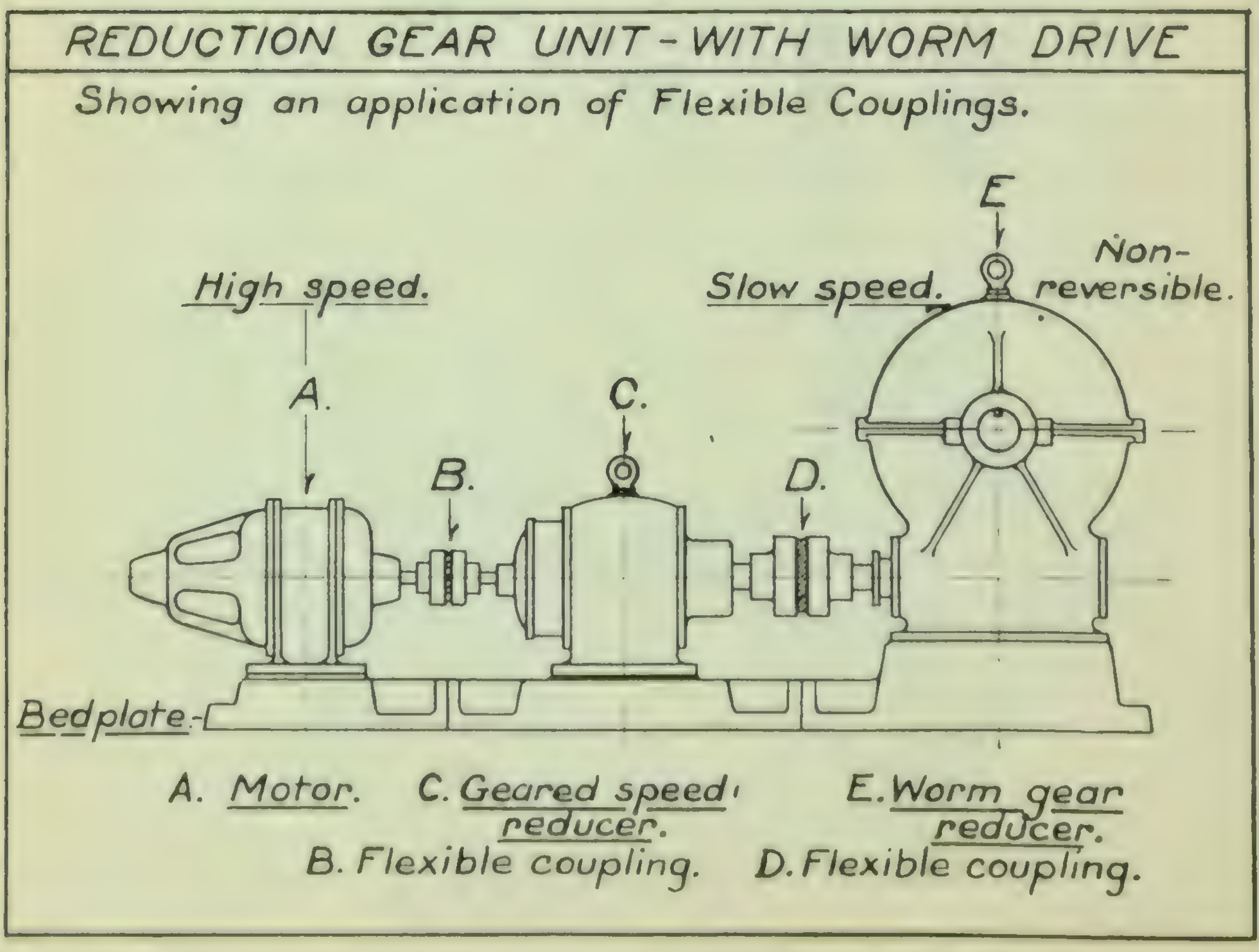
FLEXIBLE COUPLINGS.



2. On a 9″ x 12″ piece of drawing paper draw the rubber disc coupling, diagrams 3, 4 and 6, assembled. The upper half in section, and the lower half in elevation, and add an end elevation. Sizes: A=1″; B=1″; C=½″; D=3″; E=7/16″; H=1¾″. Pins ¼″ diameter. Screw threads ⅜″ diameter. Estimate other sizes. (Scale 1½ times full size or 1½″=1″.)

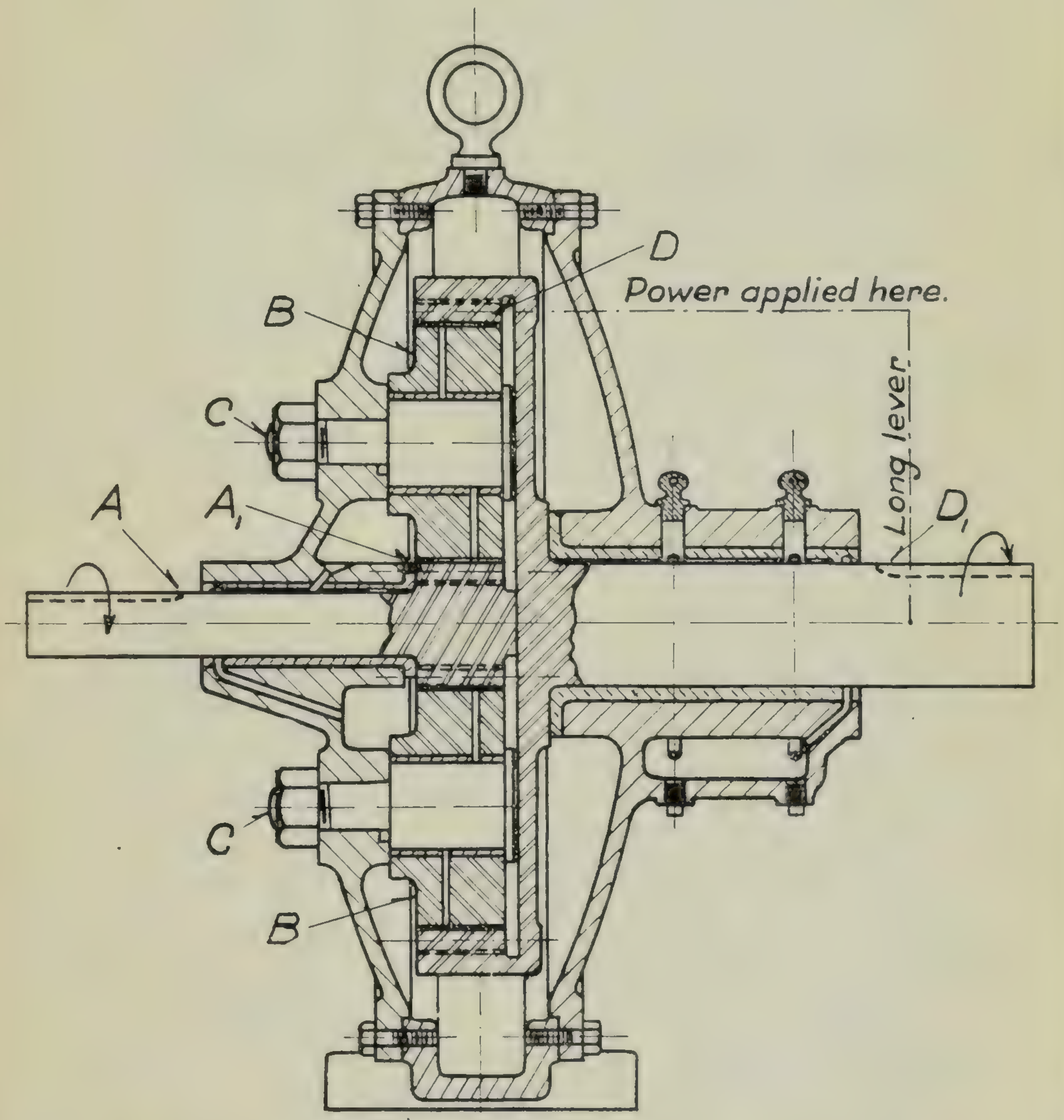
3. On a 9″ x 12″ piece of drawing paper draw diagram 7 with upper half in section and lower half in elevation, and add an end elevation of diagram 8. Show 2 shafts fastened to the coupling in both drawings. Other sizes are as follows: Reduced part of pins ⅜″ diameter, pin diameter ½″, bronze bush outside diameter ¾″, length of bush ¾″, key seats ¼″ x ⅛″. Estimate other sizes. (Scale ¾ full size or ¾″ to 1″.)

The reduction gear unit shown below illustrates an application of flexible couplings in a direct drive from a motor to a worm gear reducer, giving a right angle drive and great speed reduction, with increased power.


REDUCTION GEAR UNIT - WITH WORM DRIVE

Showing an application of Flexible Couplings.

SPUR GEAR SPEED REDUCER.



A. Motor shaft. B. Pinions. C. Pins. D. Internal gear.

A_1. Drive pinion. D_1. Slow speed shaft.

A_1 = 12T. 4D.P. B = 30T. 4D.P. D = 72T. 4D.P. Scale 3" = 1'-0".

SIMPLE HORIZONTAL SURFACE CONTACT BEARINGS

A bearing is simply a device for supporting a shaft. The size of the bore of the bearing and diameter of shaft will depend on the load which has to be carried. The length of the bearing will decide the pressure per square inch on the bearing. The great problem in bearing design is to reduce friction to a minimum, and, since friction is dependent largely on pressure the size of the bearing in proportion to the load is very important.

Coefficients of Friction. Certain metals offer less resistance to movement than others when used together in bearings, that is why special bearing metals are used in contact with a rotating shaft to reduce the friction.

Lubrication. After correct metal to metal selection has been made, the selection of a suitable lubricant is most important. Its duty is to maintain a film of oil or grease between the bearing surfaces to prevent a metal-to-metal contact.

Force feed or pressure lubrication. Oil is forced mechanically between bearing surfaces producing a constant and continually renewed oil film, adopted almost universally on automotive and aircraft work.

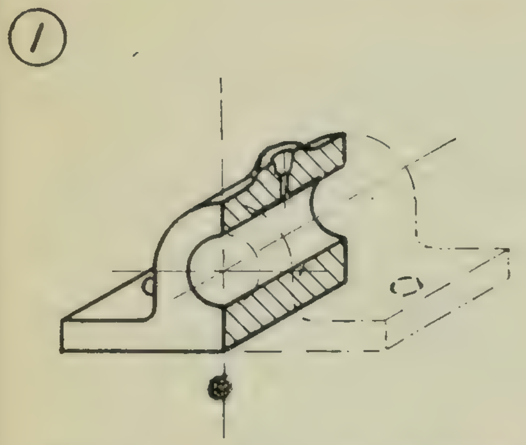
Types of Bearings.

Plain Solid Bearing (Diagram 1). This is the simplest form of bearing, consisting of a reamed hole in a cast iron pillow block. It is used for slow speed shafts, hinge pin supports, or supports for control rods where there is only a partial turning or sliding motion. Cast iron has its carbon in the free or graphite form, so that for slow speeds with low pressure per square inch, the graphite in the metal helps to reduce friction. In addition to this, provision is made for lubricating the bearing.

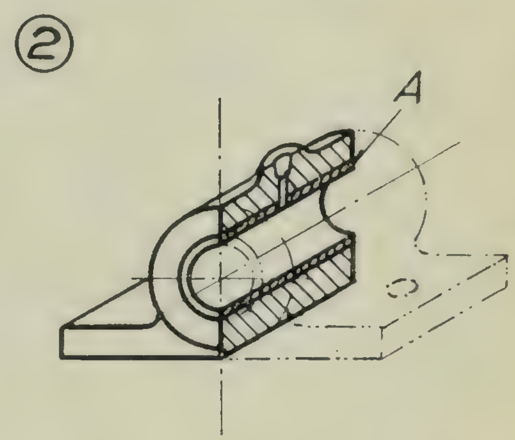
Lined Solid Type Bearing (Diagram 2). This bearing is made of cast iron with a bronze or babbitt lining fitted at A. It is used for a large variety of work where parts can be taken apart by sliding the shaft out of the bearing. The disadvantage of this type of bearing is that there is no adjustment for wear other than to renew the lining.

Babbitt Lined Split Type Bearing (Diagram 3). The babbitt is anchored to the bearing by running it in when molten into dovetail slots (c), or drilled anchor holes. Various qualities of babbitt may be used according to the duty the bearing has to perform. The cap B can be removed and adjustment made to take up wear. This bearing is used for line shafting supports, and may be installed direct or fastened to a sole plate to give vertical and side adjustment. Note the slotted holes in the base to allow for adjustment. Laminated liners or shims are fitted at joint D to regulate working clearance between the bearing metal and shaft.

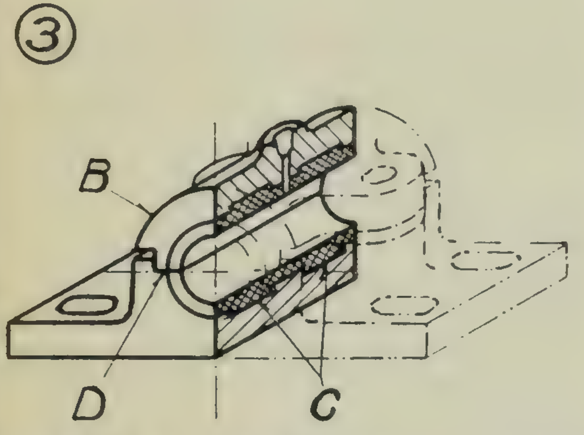
SIMPLE HORIZONTAL SURFACE CONTACT BEARINGS



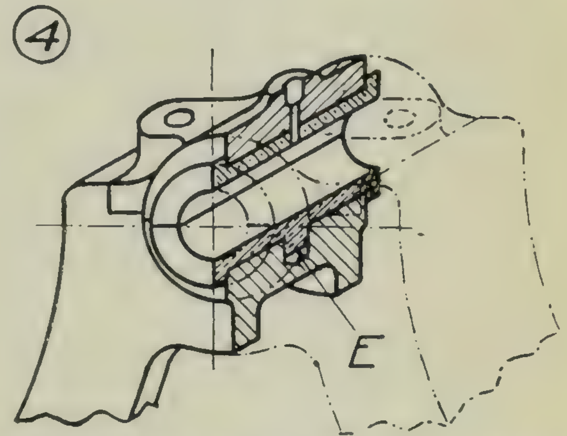
PLAIN SOLID TYPE



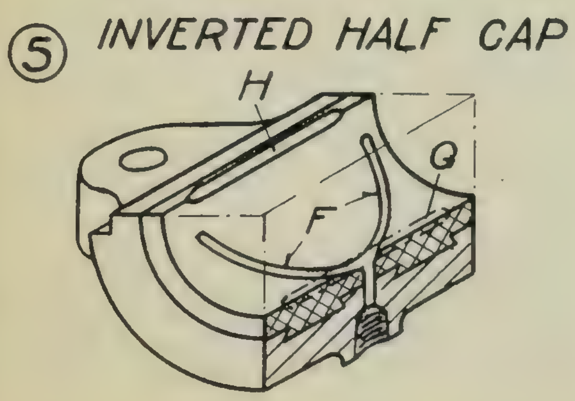
LINED SOLID TYPE



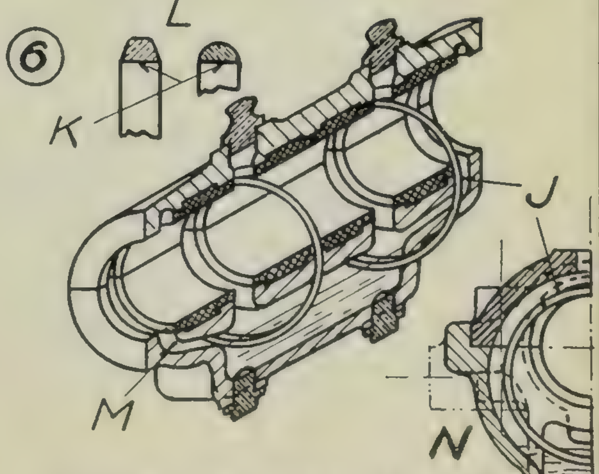
BABBITT LINED SPLIT TYPE



BRONZE LINED SPLIT TYPE



LUBRICANT DISTRIBUTION



RING OILING TYPE

Bronze Lined Split Type Bearing (Diagram 4). This bearing is made of cast iron and fitted with a bronze lining made in two parts. The lining is flanged at both ends to prevent it from being pushed out of the bearing, and to give an end bearing to a collar or flange on the shaft. A spigot marked E prevents the lining from turning with the shaft. Sometimes a dowel pin is fitted to prevent the turning action, or the bearing steps may be so shaped on the outside that they cannot turn.

Distribution of Lubricant. Diagram 5 shows an inverted bearing cap with a babbitt lining showing the grooves or oil channels which are cut in babbitt to distribute and retain sufficient oil to cover the shaft as it rotates in the bearing. Spiral grooves, marked F, or axial grooves, marked G, and a bevelled edge at H. These grooves must terminate within the bearing, otherwise the oil would run out at the ends.

The bearing bores must be slightly larger than the shaft that rotates within them to allow for the oil film and expansion due to heat. The tolerance between a shaft and a bearing surface varies greatly according to types, duty, and other conditions.

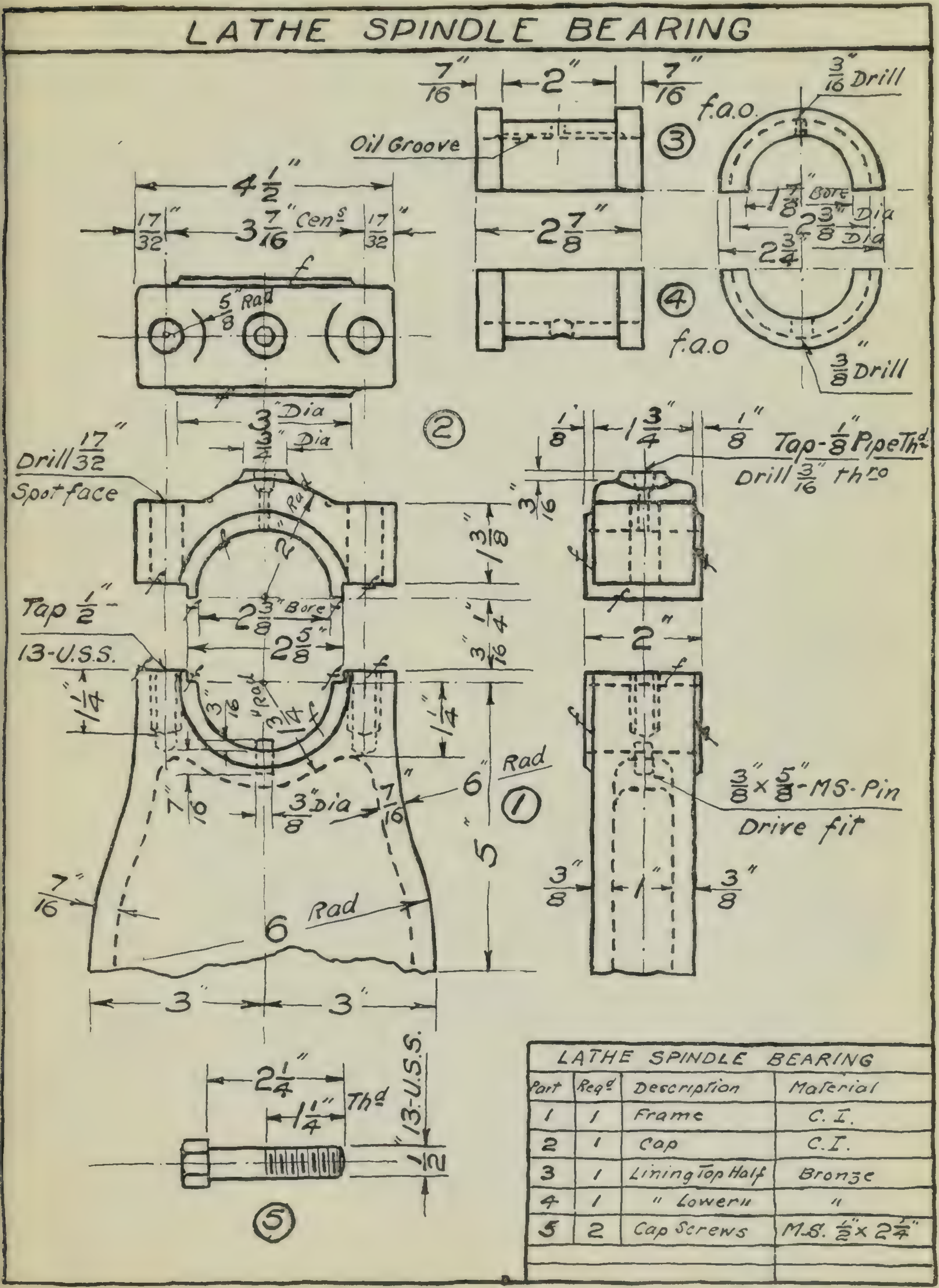
Ring Oiling Type Bearing (Diagram 6). This type of bearing is largely used in electric motors and better class bearing installations, particularly those that are not easy of access. One or more rings, usually made of bronze, shown at J and in section at K and L, run in a raceway in the bearing and hang on to the shaft. As the shaft rotates, the rings rotate and pick up oil in the oil well below. The correct oil level may be checked by an inspection glass or cap. The sections at K and L show the spreading effect given to the oil by the shape of the ring. The oil flows along the bearing surface and passes down to the well through the channels at M on both ends. A half-section of the bearing is shown at N, showing the ring resting on the shaft and dipping into the oil well.

Exercises.

1. On a 9″ x 12″ piece of paper, sketch an end elevation of each of the bearings shown in diagrams 1, 2, 3 and 4. Show the shaft in place approximately 1¼″ diameter.

2. On a 9″ x 12″ piece of paper, draw the plan, end elevation and a section front elevation when cut vertically through the lathe spindle axis of the lathe spindle bearing. (Details provided on page 119.) Show all parts of the bearing fastened in place without the lathe spindle.

3. Make workshop freehand sketches of a lathe or other machine bearing similar to the ones shown in the lathe spindle bearing.



LATHE SPINDLE BEARING

Part	Req^d	Description	Material
1	1	Frame	C. I.
2	1	Cap	C. I.
3	1	Lining Top Half	Bronze
4	1	" Lower "	"
5	2	Cap Screws	M.S. $\frac{1}{2}$" × $2\frac{1}{4}$"

Freehand Sketches

ANTI-FRICTION BEARINGS

It has been estimated that 50% of the horse-power of all prime movers is consumed in overcoming friction. If we burn coal for the production of steam and convert this potential energy into mechanical power, it will be transferred to machines by shafting resting in bearings, and one-half of the initial latent energy will be lost when the conversion takes place. A considerable proportion of this loss takes place in overcoming friction in transmission equipment.

Main babbitt bearing (Diagram 1). A babbitt box is long and has a large bearing surface and even when provided with a proper lubricant the action between the shaft and the bearing surface is one of rubbing. If the oil film is not sufficiently strong to separate the metals they rub and grind against each other, heat up and fail.

Anti-friction bearing (Diagram 3). This type of bearing consists of a shaft fastened to an inner race (D) which rotates with it on a row of steel balls or rollers held in a retainer at (C). A rolling action takes place within the outer stationary raceway (B), which is held in the casing or housing (A). The function of the retainer or cage is strictly to space and separate the balls or rollers to ensure an even load carrying distribution. As proof that anti-friction bearings do reduce friction as compared to plain bearings, the following particulars are given:—

Type of Bearing	Power Consumed in Friction	Coefficient of Friction	Power Units Consumed
Babbitt Bearings........	72 watts	.0060	3 to 4
Roller Bearings..........	54 ,,	.0045	2.2 to 3
Ball Bearings..............	18 ,,	.0017	1

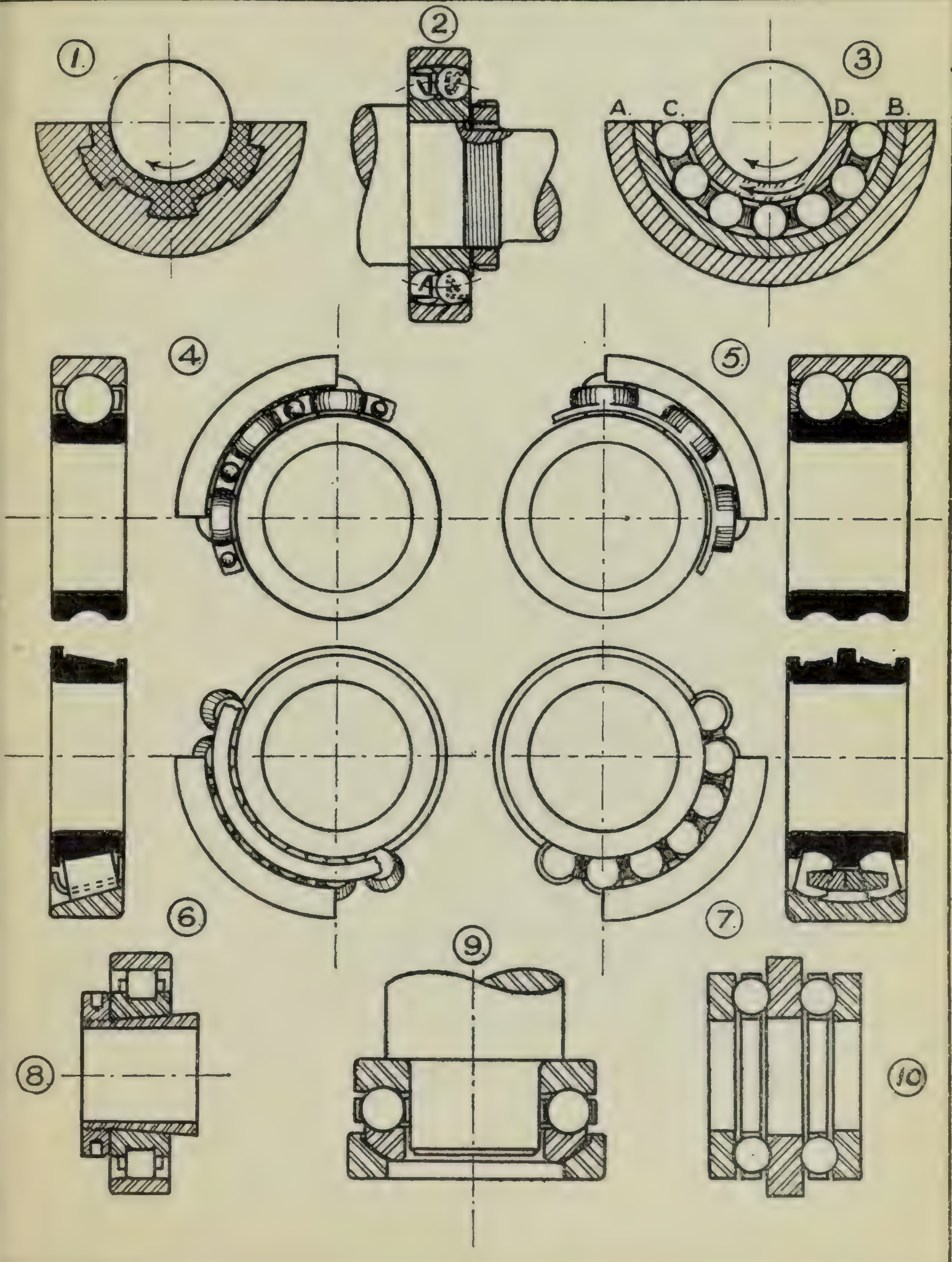
Self-aligning double-row ball bearing (Diagram 2). This shows the inner raceway fitted to the reduced part of a shaft. A threaded nut presses the raceway to the shoulder and the nut is locked in position. (See locking devices on page 81).

The outer raceway is a perfect spherical surface and may be tilted in any direction and still support the balls, so that compensation is made by the bearing for shaft deflection. The ball retainer shown in diagram 2 is made of pressed steel in one piece.

Deep groove type ball bearing (Diagram 4). This type of bearing will carry radial loads, thrust loads, or any combination of the two. The retainer is made of pressed steel in two separate halves which are riveted together.

This type of bearing is used in loose pulleys, clutch pulleys, and all loose drives. Its deep uninterrupted groove construction gives it exceptional load-carrying capacity, and enables it to withstand end thrust in either direction.

ANTI-FRICTION BEARINGS.



Double row deep-groove type ball bearing (Diagram 5). This bearing is similar to the deep groove bearing shown in diagram 4. It is equivalent to two of these bearings placed side by side, except that the inner and outer raceways are each in one piece. The retainer for the double-row bearing is made with straight prongs which are bent into shape after it has been put into the bearing. The cages are put on each row of balls from the outside and therefore cannot be riveted together. Both rows of balls always share the load whether it be radial, thrust, or combined load.

Self-aligning roller bearing (Diagram 7). Roller bearings differ from ball bearings because they use a "line" contact, while ball bearings use a "point" contact. The rollers must be guided by the raceway to maintain the line of contact.

The "line" contact provides a greater bearing surface under pressure at the loaded points on the races, therefore the roller bearing has a greater capacity than ball bearings for normal loads, shocks and overloads.

The spherical surface of the outer race makes the bearing self-aligning. The rollers are guided by the centre part of the inner raceway, the rollers being slightly conical, are forced against this centre wall. The rollers may be opposite each other as shown, or they may be staggered.

Tapered roller bearing (Diagram 6). These rollers are conical in shape, and are fitted into slots in a one-piece pressed steel retainer. The tapered rollers are guided by the grooves in the inner raceway, and are used where end thrust is prevalent. The angle of the roller axis is increased to carry heavy thrust loads.

Adapter roller bearing (Diagram 8). Adapters such as the one shown in this diagram, are applied to ball and roller bearings.

The inner race is secured to the shaft by an adapter sleeve. The sleeve is split, having a cylindrical bore to fit the shaft, and is tapered on the outer surface to fit the taper of the inner race. The small end of the sleeve is threaded and fitted with a lock nut.

The cylindrical rollers are held between two retainer plates which are riveted together. The inner raceway guides the rollers as they run in the groove provided for them.

Thrust ball bearings (Diagrams 9 and 10). Diagram 9 shows a vertical shaft to which is fastened a grooved plate running on balls held in a retainer. The lower grooved plate has a spherical seat which sits in the lower self-aligning washer, forming a part of a **Footstep bearing.**

Diagram 10 shows a two-direction thrust bearing with flat seats.

Exercises.

On a 9″ x 12″ piece of drawing paper, sketch with the aid of a pair of compasses, the parts of anti-friction bearings shown. Omit diagram 1 and re-arrange diagrams 2 and 3.

ANTI-FRICTION BEARING PILLOW BLOCK

You have already studied the lesson on "Anti-friction bearings," so that you should be familiar with the various types of bearings used. This lesson presents a self-aligning, double row ball bearing mounted in a Pillow Block housing ready for use. The drawings represent the various parts, detailed for your information and you will be required to make a detail and assembly drawing of the complete bearing.

Pillow block, diagrams 1 and 2. **View (A)** shows a plan, the left-hand side of the centre line shows the plan with the cap in place and the right-hand side shows the cap removed.

View (B) shows a half sectional elevation of the cap and base separated, the right half being in section when cut on the line (JK) shown in the plan.

View (C) shows the bottom or inverted plan or underside view of the base of the pillow block, showing the method used to lighten and strengthen the casting, with an outer rim to ensure a true bed for the bearing.

View (D) shows an end sectional elevation on the cutting plane (GH), diagram 2, giving the interior details of the cap and base of the pillow block housing.

View (E) shows an enlarged part sectional elevation to present the shape of the felt groove (F). The felt groove is provided to hold a circular ring of felt to prevent foreign matter from entering the bearing and also to prevent any escape of lubricant from the inside of the bearing. The tapered section produces a tendency to force the felt against the shaft.

Lubrication. The lubricant enters the bearing through the hole in the cap which is tapped for ⅛″ pipe and made to be closed with a pipe plug or fitted with an alemite fitting. The lubricant passes along the oil groove shown in diagram (D), so that it may pass down the sides of the outer raceway to the balls and inner raceway. This type of bearing will run safely, in some instances, for one year with one charge of lubricant. Drain plugs are provided in the base shown in section at (D) for cleaning out the used lubricant.

Fitting the outer raceway into the pillow block. The pillow block is bored out 1.8512″ diameter to receive the outer raceway which is 1.8504″ diameter. The recess in the pillow block is 0.906″ wide and the outer raceway of the ball bearing is 0.5512″ wide, so that the ball bearing could move parallel to its axis in the pillow block.

In a line shaft where several bearings are used, one bearing is selected as the stabilizer and a side ring is placed on either side of the outer raceway with a side clearance of 0.010″.

Fitting the ball bearing to the shaft. The inner raceway shown in diagram 7 is fastened to a shaft by the tapered split adapter shown in diagram 8. The lock-nut shown in diagram 9 is fitted on the threaded adapter and draws the tapered part of the adapter into the tapered bore of the inner raceway, which tends to close the split in the adapter and grip the shaft. It is locked in position by the lock washer, diagram 10, which was explained in the lesson on "Locking Devices" (page 81).

Ball bearing sizes are frequently expressed in millimeters, these sizes have been translated into decimals on the detail drawing shown in diagram 7.

Exercises.

1. On a 9″ x 12″ piece of drawing paper make detail drawings as shown.

Scale for pillow block 6″ = 1′-0″.

Scale for ball bearing, nut, adapter and lock washer 12″ = 1′-0″

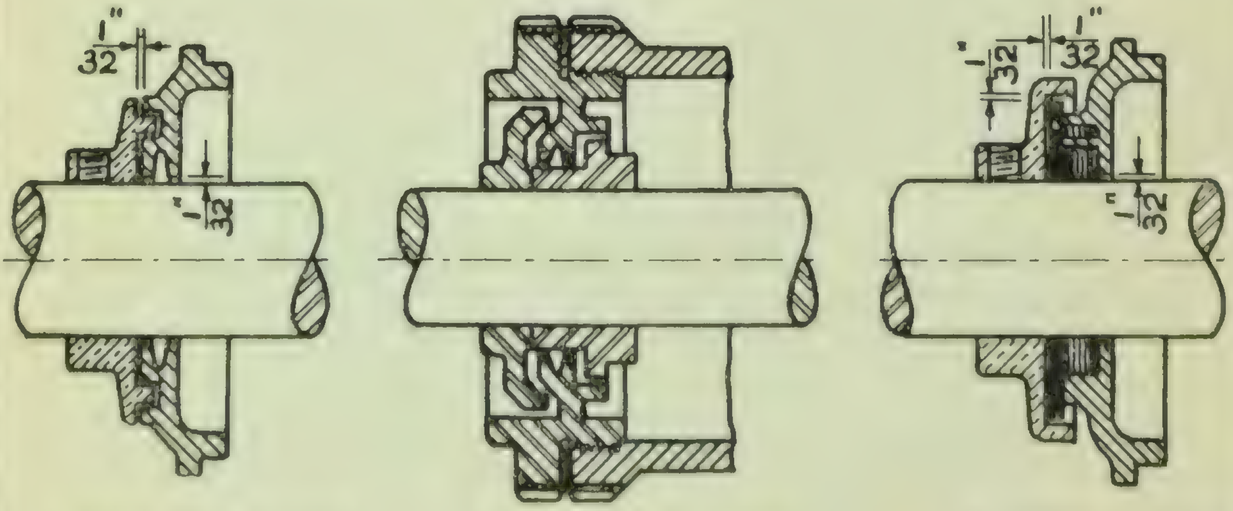
2. On a 9″ x 12″ piece of drawing paper draw a plan, front elevation, (with pillow block half in section) and a complete sectional end elevation of all details assembled in their proper positions.

Scale full size.

Put in reference numbers and omit all dimensions and title in this question only.

HOUSING SEALS.

"exclude dirt-retain lubricant."

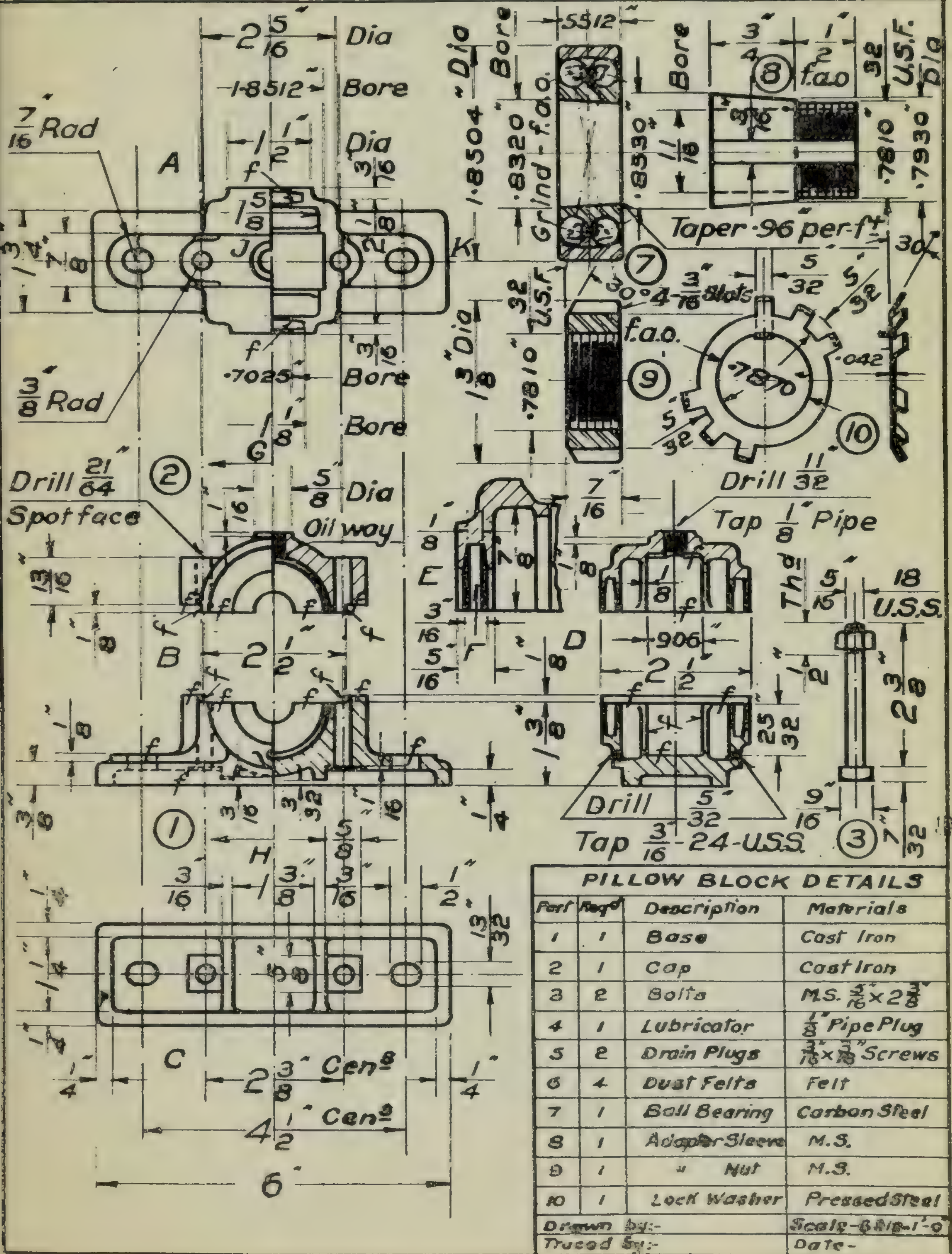


Labyrinth type & oil or grease groove.

Internal & external flingers & oil or grease groove.

Flinger type & felt washer.

ANTI-FRICTION BEARING PILLOW BLOCK



PILLOW BLOCK DETAILS

Part	Reqd	Description	Materials
1	1	Base	Cast Iron
2	1	Cap	Cast Iron
3	2	Bolts	M.S. $\frac{5}{16}$" × $2\frac{3}{8}$"
4	1	Lubricator	$\frac{1}{8}$" Pipe Plug
5	2	Drain Plugs	$\frac{3}{16}$" × $\frac{3}{16}$" Screws
6	4	Dust Felts	Felt
7	1	Ball Bearing	Carbon Steel
8	1	Adapter Sleeve	M.S.
9	1	" Nut	M.S.
10	1	Lock Washer	Pressed Steel
Drawn by:-			Scale-6 ins-1'-0"
Traced by:-			Date-

VALVES

The function of a valve is to control the flow of a substance through an aperture. A valve may be opened rapidly and often or slowly and seldom. It may be operated mechanically or by hand. The most common applications of a valve are on pipe lines which may be used to convey water, steam or gas. Special precautions are taken for certain chemical solutions.

The valve most familiar to the average individual is the common water tap or faucet, which may be classified as a small stop valve constructed on the same principle as the valve shown in sectional elevation in diagrams 11 and 12.

Examples of Common Valves.

The valves illustrated in this lesson are selected from the many types used in general engineering practice with the object of presenting types without dealing with conditions governing the substances conveyed. To avert serious trouble it is essential that large stop valves (such as is shown in diagram 20) should be opened and closed slowly, they are therefore constructed to ensure this end.

With steam pipe lines the accumulation of water from condensation will cause "water hammer" when driven along by high velocity steam and may cause serious damage.

With long, high head water pipe lines, if an attempt is made to stop a moving column of water suddenly it would be almost as bad as trying to hold back a projectile in flight.

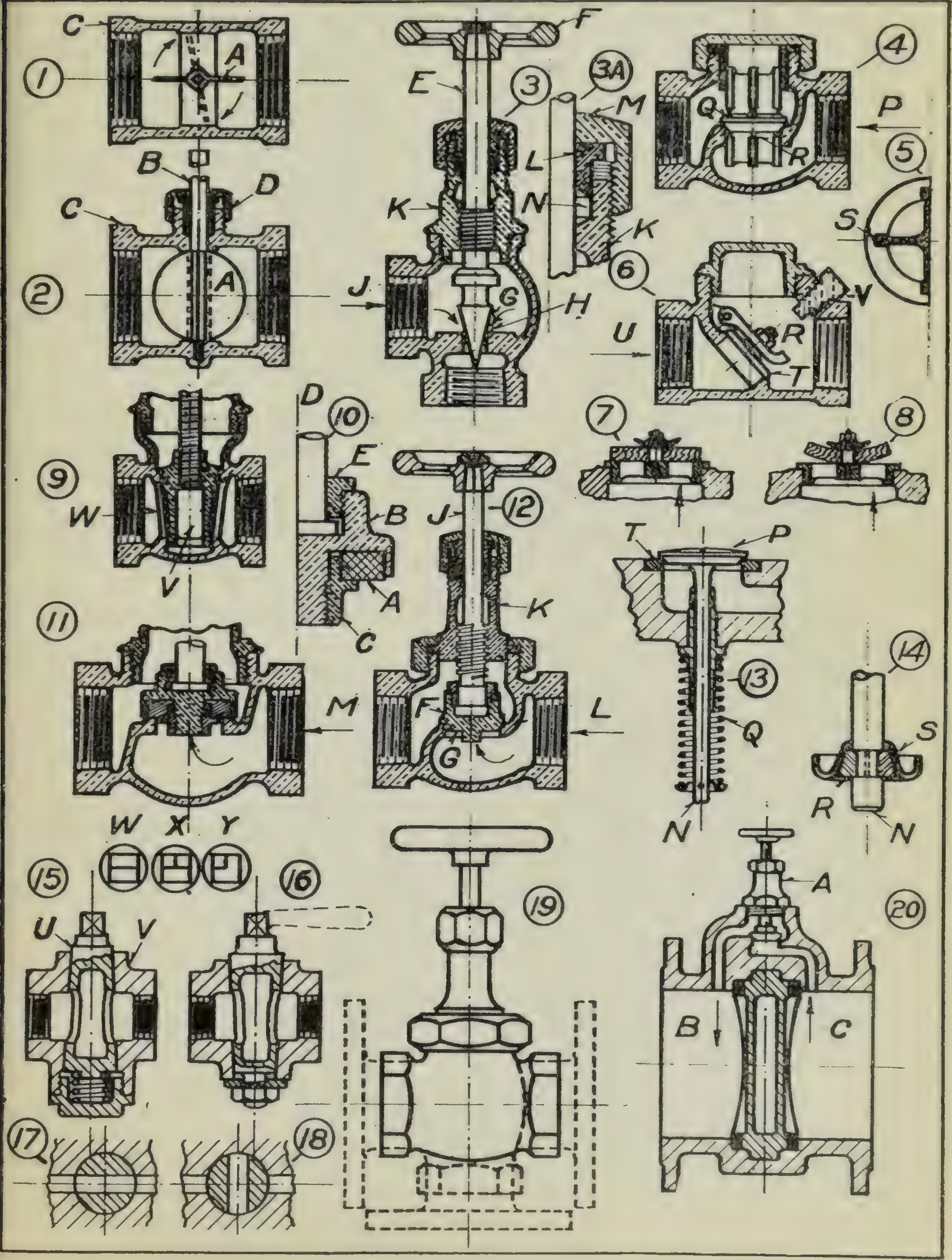
With this brief introduction we shall now consider the features of each valve illustrated.

Throttle valve. Diagram 1 shows a "butterfly valve" of the throttle type in sectional plan, and diagram 2 shows the same valve in sectional elevation. The body of the valve (C) is threaded at both ends for pipe connections. The valve proper (A) is a thin circular disc attached to a spindle (B) so that the valve may be turned on or off. The valve is shown open and the dotted lines indicate the position when closed. A gland and stuffing box (D) is provided to seal the spindle movement, an enlarged drawing of a stuffing box is shown in half sectional elevation in diagram 3A.

Other types of throttle valves are used for high pressures, such as a steam engine, where the control is obtained by sliding a flat valve over ports or openings, the pressure holding the surfaces in tight contact.

Needle valve. Diagram 3 shows a needle valve in sectional elevation. The threaded spindle (E) is controlled by a hand wheel (F). The spindle has a conical point (G) and may be adjusted up or down to govern the amount of the aperture at the seat of the valve (H). The great difference between the area of the pipe and the size of the aperture at the valve seat causes an increase in the velocity of the liquid being conveyed. This feature is made use of in atomizers on oil burners and any other place where the supply control requires a fine adjustment.

VALVES


C
①
A
B
D
C
②
A
F
E
③
③A
M
L
K
N
K
J
G
H
④
Q
P
R
⑤
S
⑥
V
U
R
T
D
⑩
E
B
A
C
⑨
W
V
J
⑫
K
F
G
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⑪
M
⑦
⑧
T
P
⑬
Q
N
⑭
S
R
N
W
X
Y
⑮
U
V
⑯
⑲
A
⑳
B
C
⑰
⑱

The stuffing box of this valve is shown enlarged at (3A) showing the stuffing box (K), the packing follower (L), the gland (M) and the packing space (N). In larger valves, studs or bolts would be substituted for the threads on K and M.

Gland packing is known by various trade names and varies in composition from cotton yarn base to high grade asbestos and rubber combination.

Check valve. Diagram 4 shows a sectional elevation of this valve which is of the non-return type. It is so constructed that a liquid is free to flow in one direction only, as indicated by the arrow (P) at the inlet end. The pressure flow entering the valve at (P) would raise the valve (Q) and passing through the opening at (R). The valve (Q) then descends back to its seat closing the opening at (R) as soon as pressure from (P) ceases. Thus the return of the liquid is checked or prevented from returning through the valve. These valves are used on the feed water pipe lines of boilers between the feed pump and boiler inlet or in similar conditions where a non-return action is required.

Diagram 5 shows a part sectional plan of a wing valve. The edges of the wings (S) act as guides when the valve lifts, leaving a free space between the wings for flow.

Swing check valve. Diagram 6 shows a sectional elevation of this valve where the pressure flow enters at (U), raising the valve from its seat at (T). The lift is limited by the arm (R) striking the screwed plug (V).

This type of valve is used when the substance conveyed is impregnated with foreign matter.

A pump valve is shown in the closed position in diagram 7 and in the open position in diagram 8. The valve is made of a resilient substance, such as a rubber composition, which gives way under pressure and adapts itself to fit snugly to the valve seat.

Gate valve. Diagram 9 shows a wedge type gate valve. It closes the aperture by forcing the wedge shaped valve (V) into a similar shaped seat shown at (W). This type of valve is used mostly for larger sizes of valves and gives a clear, direct passage for liquids through the valve. The wedge is moved up to open the valve.

A stop valve, also known as a **Globe valve,** is shown in diagram 12 in sectional elevation. The valve (F) has a bevelled face which fits against the valve seat at (G). The valve is opened or closed by turning the threaded spindle (J) which is supported and sealed by the bonnet (K). The pressure flow is underneath the valve in direction of the arrow (L). The spindle (J) is free to turn inside valve (F); enlarged section of a similar assembly is shown in diagram 10.

A flat valve seat with a renewable disc in the valve is shown in diagram 11, and enlarged in diagram 10, showing the spindle (D) resting in disc container (B), being held in place by a clamp collar nut (E). The renewable valve disc (A) is held in container (B) by a clamp nut (C). These features provide for simple replacement with a composition-to-metal contact to provide a tight seal.

The seat of the valve in diagram 12 is bevelled usually at 45° with metal-to-metal contact having a machined and ground seat to form a tight seal.

Note—Stop valves such as those shown in diagrams 11 and 12 should be installed so that the pressure flow acts on the underside of the valve.

A spring return valve is shown in diagram 13, it is operated mechanically. The valve head (P) is lifted from the valve seat (T) (which is sometimes inserted as shown as a renewable feature) by a cam lifting the end of the valve spindle at (N), this compresses the spring which returns the valve to its seat when the pressure from the cam is released. The coil spring is held up on the spindle by a cup-shaped washer and a cotter pin. An alternative method of holding the spring to the spindle (N) is shown in diagram 14, with a split collar (R) fitted into the recess of the spindle and gripped by the tapered sides of the recessed washer (S). This type of valve is suitable for high speed operation, such as is necessary in automobile and aircraft engines.

A plug cock is shown in diagram 15 with a spring used to press the tapered plug (U) to its seat in the body (V) so that the valve may be turned to the open position shown in sectional plan diagram 17, or the closed position, diagram 18. Another type is shown in diagram 16, the plug is held in position by a nut and washer.

Plans of plug markings are shown at (W), (X) and (Y) to indicate when the fittings are made for one, two, three or four-way connections. The plug cocks shown are one-way connections as marked at (W).

Types of valve connections. Diagram 19 shows that a valve may have a pipe thread connection or may be made with flanges as shown by the dotted lines. Intermediate angles are also made to connect with pipes not in a straight line.

By-pass valve. Diagram 20. The illustration shows a sectional plan through a large gate valve with a small globe valve (A) on one side connected by ports to either side of the main gate valve. The pressure flow from (C) to (B) is controlled by the small globe valve as a by-pass to equalize the pressure on either side of the main valve before it is opened.

Exercises.

1. On a 9″ x 12″ piece of drawing paper sketch freehand diagrams 1, 2, 3, 3A, 4, 5, 6, 7, and 8 and arrange them to suitably fit the paper.
2. On a piece of writing paper write out a concise description of the valves sketched in question 1.
3. On a 9″ x 12″ piece of drawing paper sketch freehand diagrams 9, 10, 11, 12, 13, 14, 15, 16 and 20 and arrange them to suitably fit the paper.
4. On a piece of writing paper write out a concise description of the valves sketched in question 3.

"POP" SAFETY VALVE ASSEMBLY

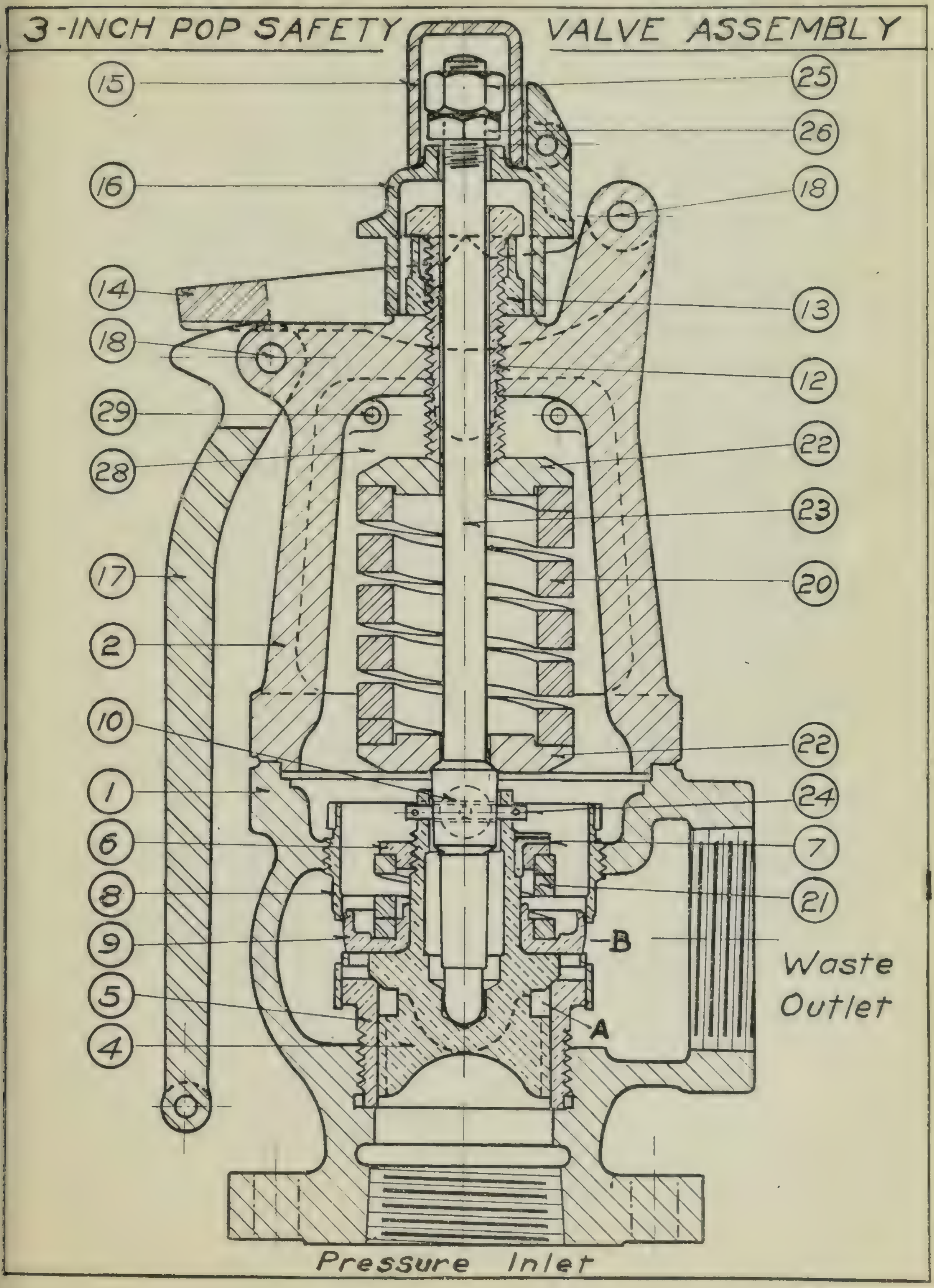
A safety valve is a device to automatically release surplus undesired pressure from a boiler to avert a possible explosion. A complete set of detailed drawings of this valve are provided for your information. You are advised to make the drawings of the details before starting the assembly drawing, so that you may become familiar with the various parts of the valve.

The smaller sized valves are made with a bronze body, the larger types such as the one shown, are made of cast iron or semi-steel with bronze and cast steel working parts. The valves are made to meet rigid inspection standards of boiler inspectors.

After the general introductory lesson on valves you should be able to grasp the general principles of the "pop" safety valve. The pressure of steam is exerted on the underside of the valve, (4), and by raising the valve against the pressure of the spring it may escape through the waste outlet pipe. To examine this action in detail, one can realize how an escape of steam under slight excess pressure will injure the valve seat by cutting grooves in the surface. The "pop" safety valve is designed to give a quick snappy escape of the steam followed by a quick closing action of the valve. In other words, it goes off "pop". The following description gives the movement of the valve in detail.

Valve action. Assume that an excess pressure seeks release; the pressure enters the lower part of the body (1) at the "pressure inlet" and exerts pressure on the underside of the valve (4) on the 3″ area only. (**Note** how the guiding wings of the valve are notched immediately under the disc at (A) for the purpose of making available the full circumferential opening of the valve. The notches also prevent any possible cutting of the valve seat.)

The valve assembly is raised under pressure. The moving parts are (4), (9), (21), (6), which lift also the stem (23) which raises the collar (22) and compresses the main spring (20). The lifting of the valve (4) allows steam to escape between it and the bevelled seat of the valve shown marked at (5). This escape outlet still confines the steam inside the valve cage (8) but free to enter the 16-3/8″ holes around the extension flange of valve (4) to exert pressure on the underside of escape disc (9). The disc (9) is raised which compresses the compensating spring (21) which may be adjusted by nut (6) and locked when set with pin (7). The pressure exerted on disc (9) will be transferred through spring (21), nut (6), pin (24), to stem (23) to further compress main spring (20) and permits valve (4) more lift and allows the steam to blow through the four escape ports (B) in the valve cage (8). The vertical position of these escape ports may be adjusted and locked by the screw (10) which is tapped into the valve body (1). The point of the screw (10) engages with one of the 40 slots around the top of the valve cage (8)


3-INCH POP SAFETY VALVE ASSEMBLY
B
A
Waste Outlet
Pressure Inlet

Note how part (9) has a crowned surface which slides in contact with the inside bore of the cage (8) to avoid any binding action by uneven lift.

The pressure on the main spring (20) is adjusted by a screw (12) and locked by a nut (13). The nut length may be made to suit a required pressure adjustment. To ensure that a safety valve has not become stuck or is not free to release excess pressure, an easing gear is fitted. The easing gear consists of a lever (17) which, when raised, would lift a forked arm (14) which presses against the underside of extended flange of lifting collar (16), which in turn lifts the valve stem (23) and valve (4) through nuts (26) and (25). A cap (15) is shown with a hole provided for a padlock, if necessary, to prevent tampering with the parts.

The lower flange of body (1) is shown threaded for pipe for low pressure use and has 8-¾″ bolt holes for heavier pressures.

The waste steam outlet is shown threaded for piping away the steam. A drain plug hole is provided at the lowest point shown in detail drawing of part (1).

A pair of cover plates (28) are fastened through bolts (29) as a protection against any foreign substance entering the valve mechanism.

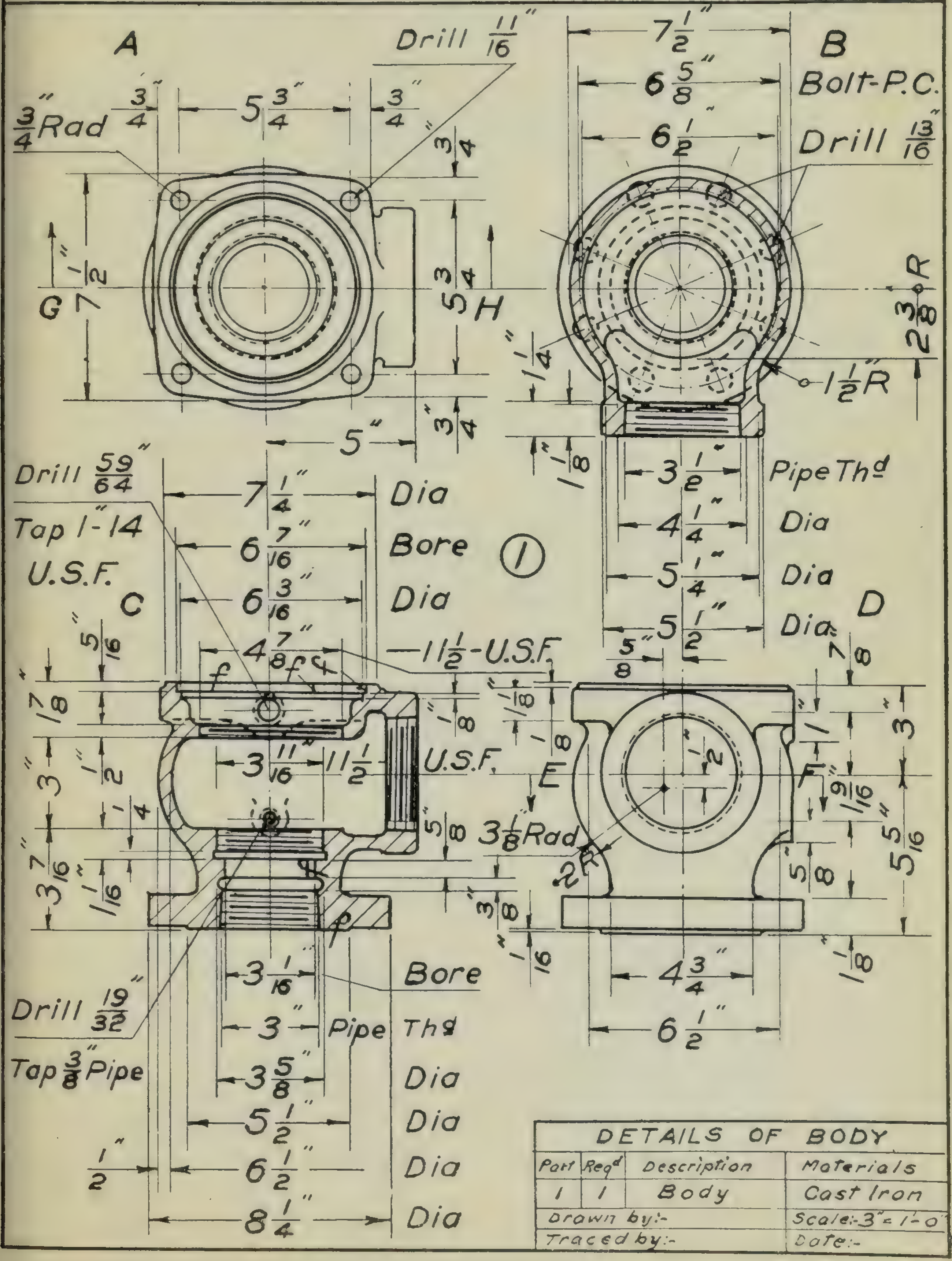
Exercises.

1. On a 9″ x 12″ piece of paper draw the assembled sectional elevation as shown from the dimensioned detail drawings provided. **Scale,** 6″ = 1′ - 0″.

2. On a 9″ x 12″ piece of paper draw an end elevation looking into the waste outlet pipe. Obtain dimensions from the detail drawings. **Scale,** 6″ = 1′ - 0″.

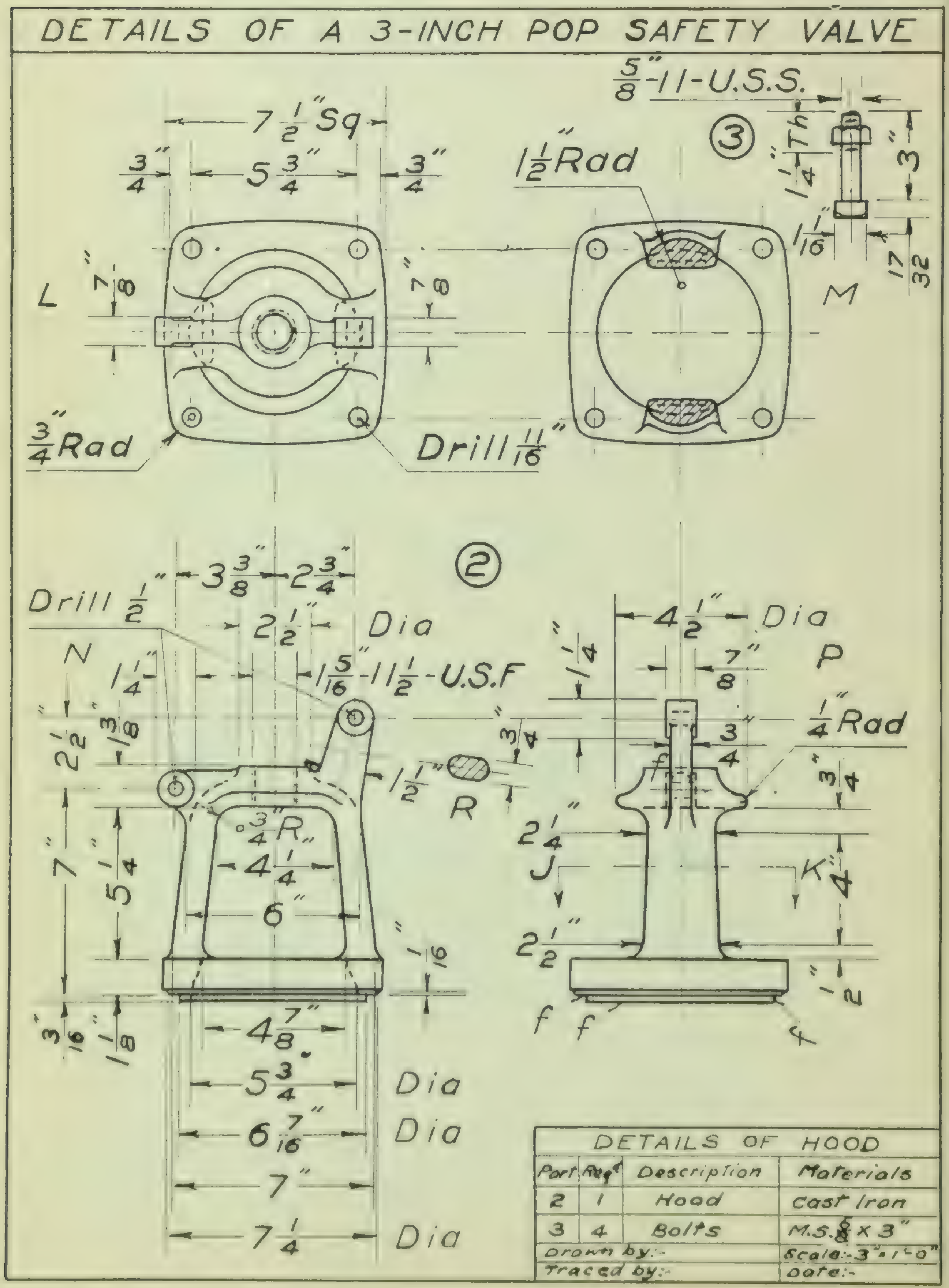
3. On 8 sheets of 9″ x 12″ paper make a full set of detail drawings of the 3″ "pop" safety valve. Scale as specified on each sheet.

DETAILS OF A 3-INCH POP SAFETY VALVE

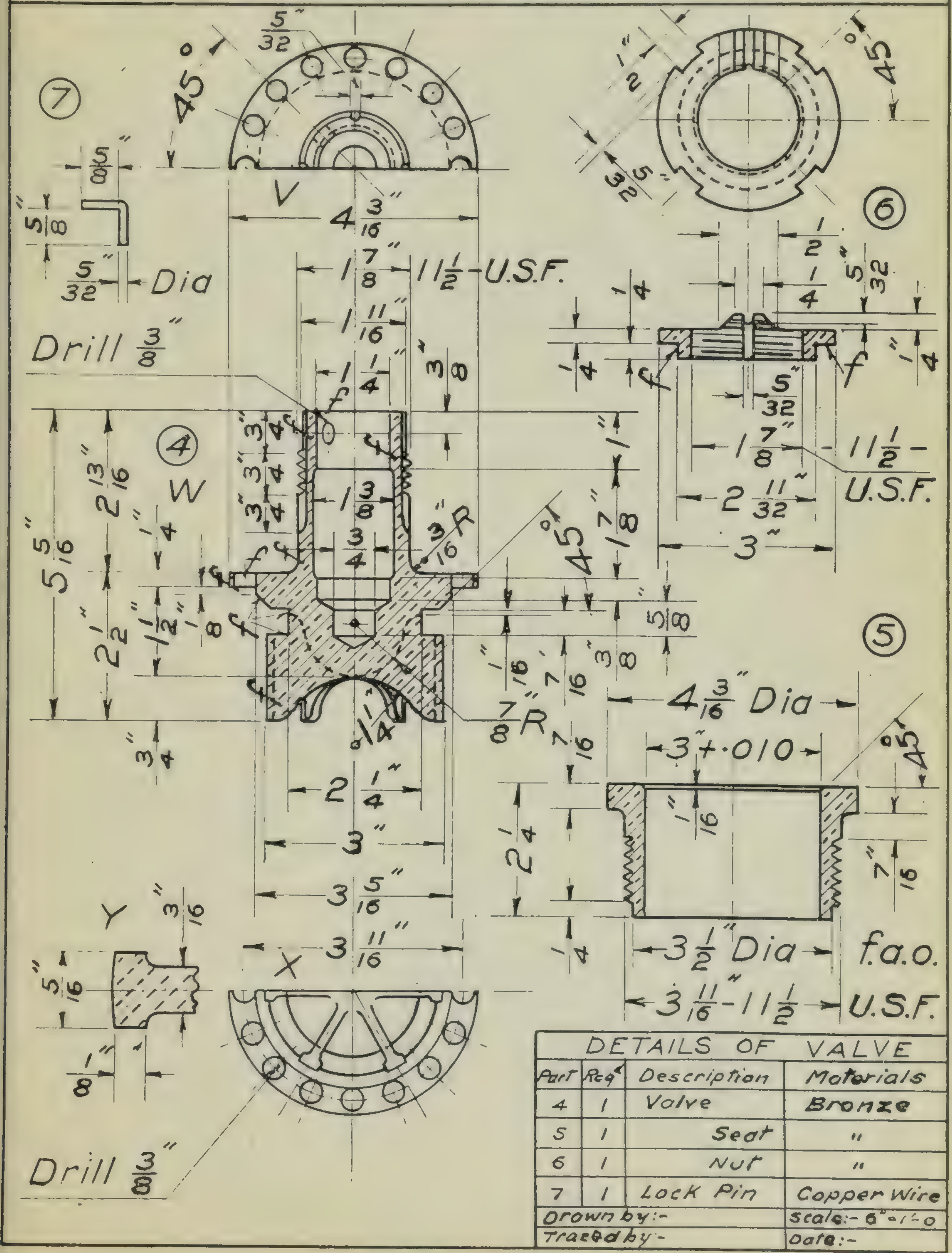


DETAILS OF BODY

Part	Reqd	Description	Materials
1	1	Body	Cast Iron
Drawn by:-			Scale:-3" = 1'-0"
Traced by:-			Date:-


DETAILS OF A 3-INCH POP SAFETY VALVE
7 1/2" Sq
3/4"
5 3/4"
3/4"
L
7/8"
7/8"
3/4" Rad
Drill 11/16"
1 1/2" Rad
③
5/8"-11-U.S.S.
1 1/4" Th
3"
1 1/16"
17/32
M
②
Drill 1/2"
3 3/8"
2 3/4"
2 1/2" Dia
N
1 1/4"
1 5/16"-11 1/2-U.S.F
2 1/2"
3/8"
1 1/2"
R
3/4"
3/4" R
4 1/4
6"
7"
5 1/4"
1/16"
3/16"
1/8"
4 7/8"
5 3/4" Dia
6 7/16" Dia
7"
7 1/4 Dia
4 1/2" Dia
P
1/4"
7/8"
3/4
1/4" Rad
3/4"
2 1/4"
J
K
4"
2 1/2"
1/2"
f
f
f
f
DETAILS OF HOOD
Part | Req'd | Description | Materials
2 | 1 | Hood | Cast Iron
3 | 4 | Bolts | M.S. 5/8 x 3"
Drawn by:-
Traced by:-
Scale:-3"=1'-0"
Date:-

DETAILS OF A 3-INCH POP SAFETY VALVE

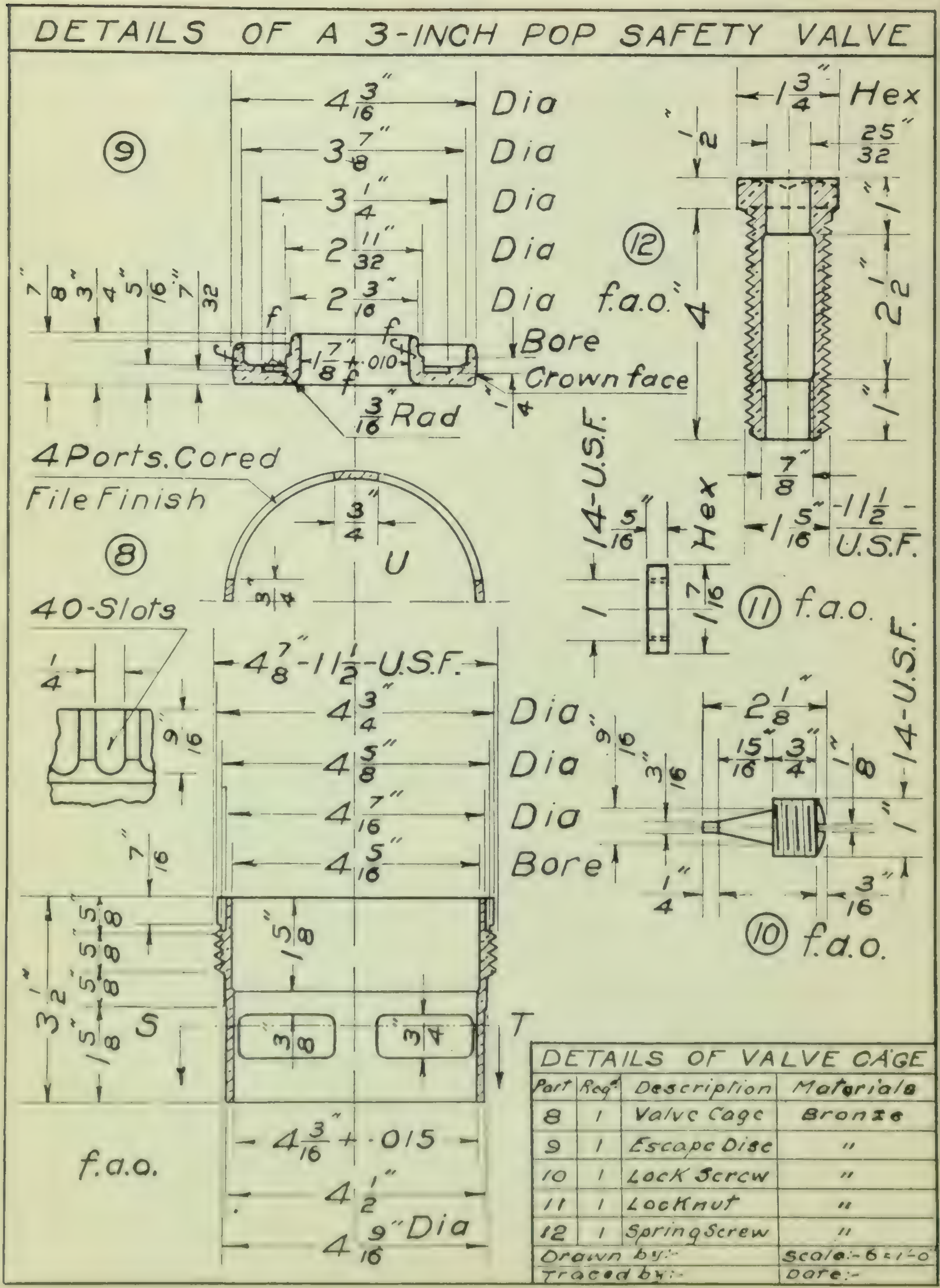


DETAILS OF VALVE

Part	Req'd	Description	Materials
4	1	Valve	Bronze
5	1	Seat	"
6	1	Nut	"
7	1	Lock Pin	Copper Wire

Drawn by:- Scale:- 6"=1'-0

Traced by:- Date:-

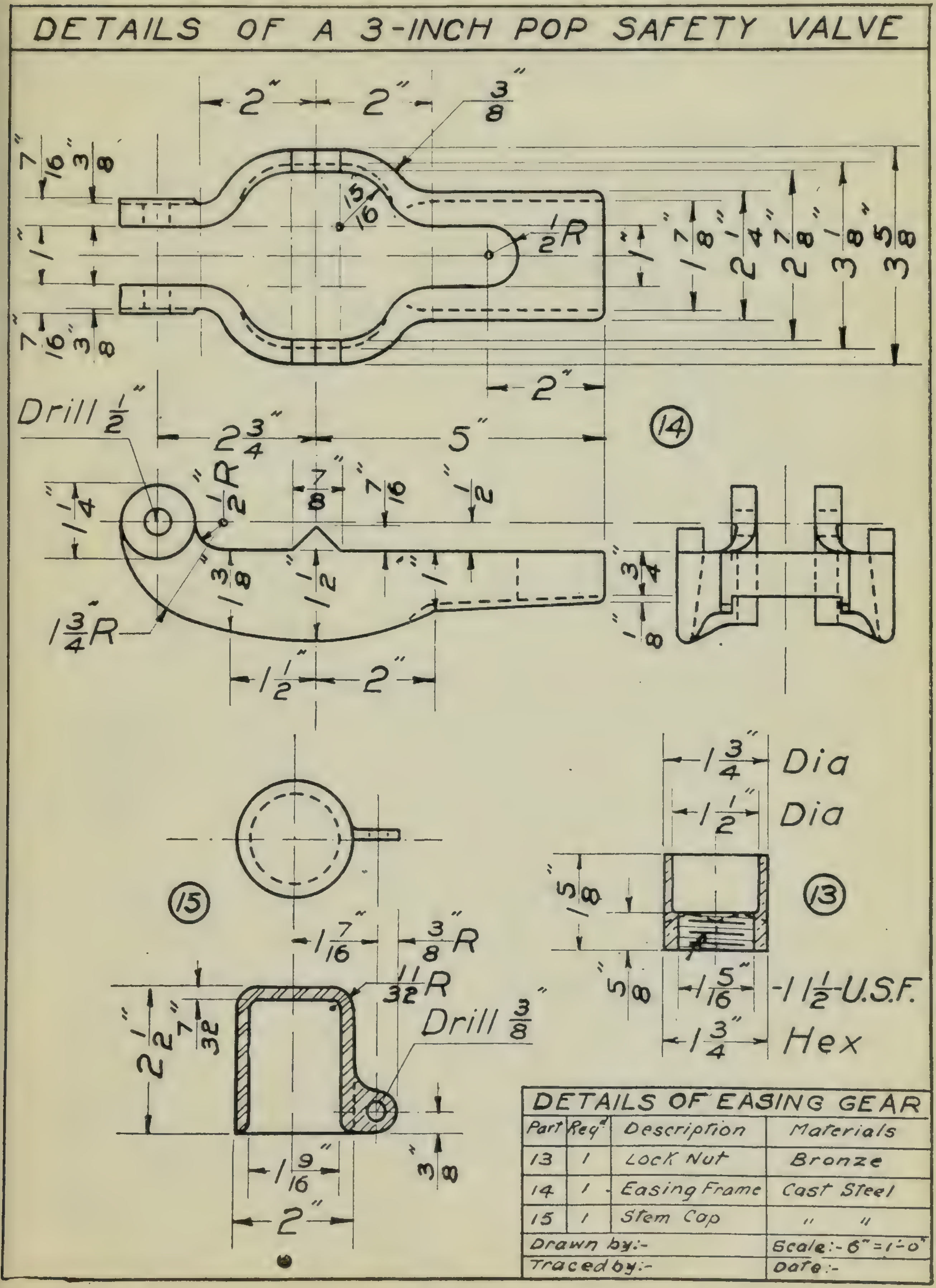


DETAILS OF VALVE CAGE

Part	Reqᵈ	Description	Materials
8	1	Valve Cage	Bronze
9	1	Escape Disc	"
10	1	Lock Screw	"
11	1	Locknut	"
12	1	Spring Screw	"

Drawn by:- Scale:- 6" = 1'-0"
Traced by:- Date:-

DETAILS OF A 3-INCH POP SAFETY VALVE



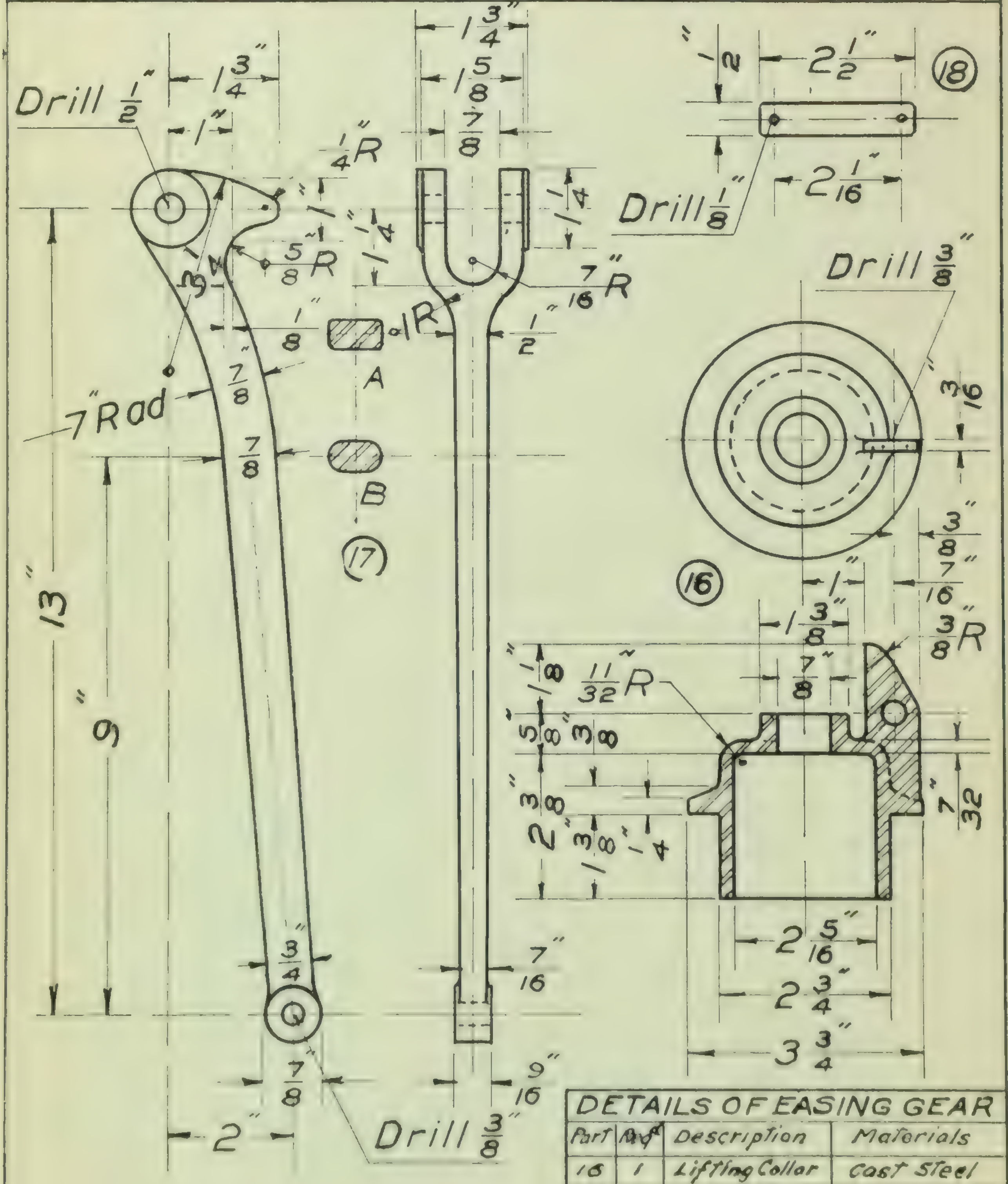
DETAILS OF EASING GEAR

Part	Req.d	Description	Materials
13	1	Lock Nut	Bronze
14	1	Easing Frame	Cast Steel
15	1	Stem Cap	" "

Drawn by:- Scale:- 6" = 1'-0"

Traced by:- Date:-

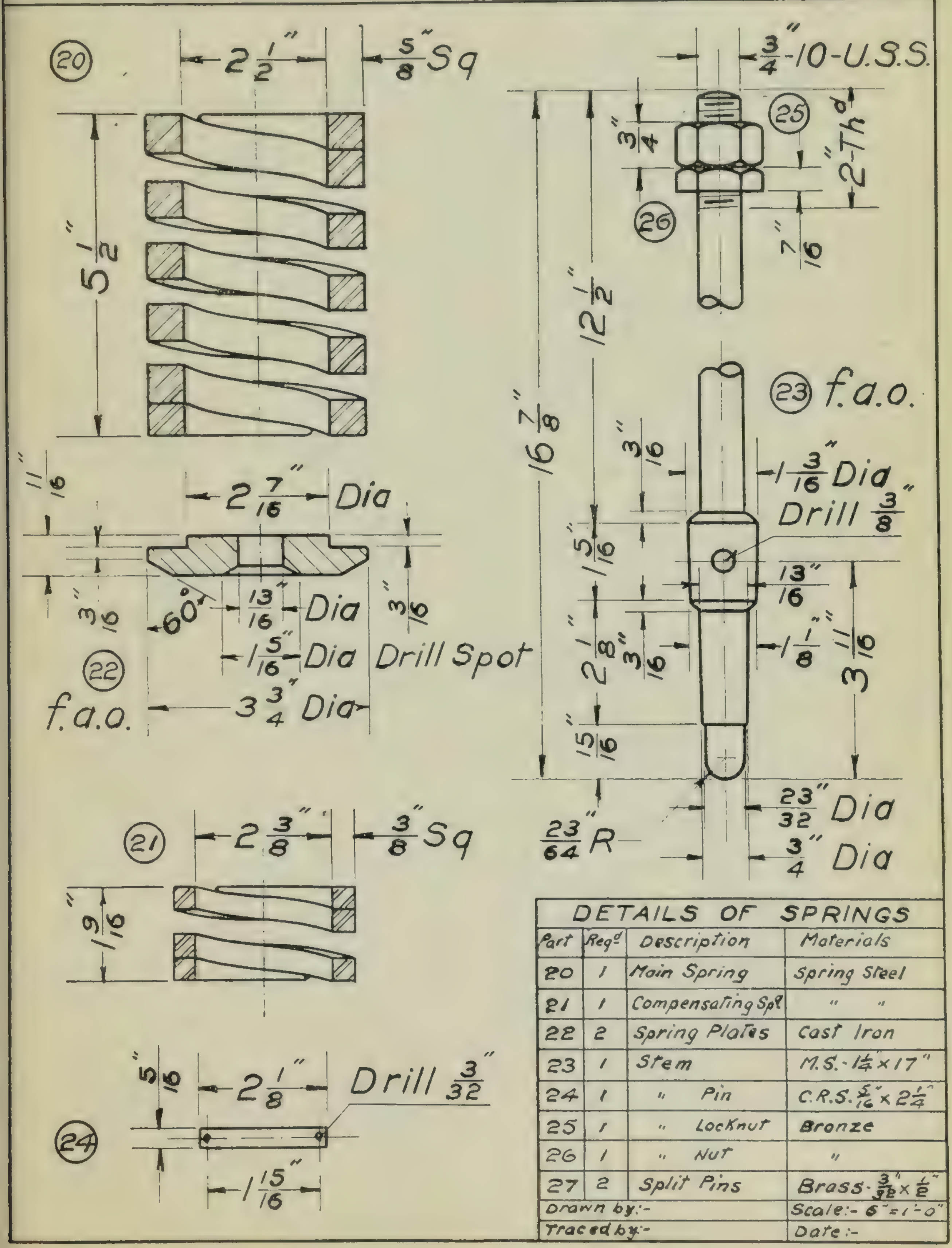
DETAILS OF A 3-INCH POP SAFETY VALVE



DETAILS OF EASING GEAR

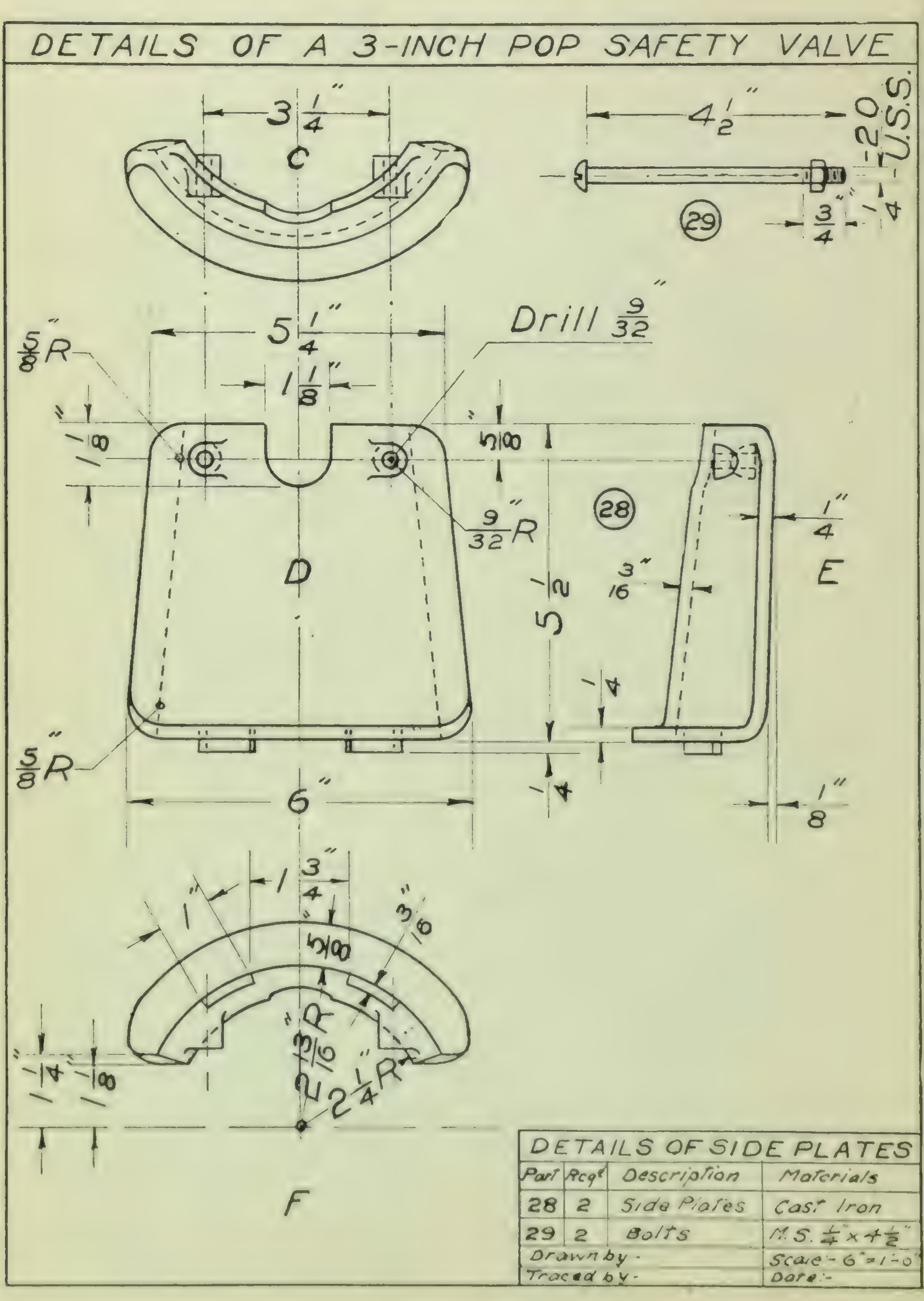
Part	Nº	Description	Materials
16	1	Lifting Collar	Cast Steel
17	1	" Lever	" "
18	2	Lever Pins	C.R.S. $\frac{1}{2}'' \times 2\frac{1}{2}''$
19	4	Split Pin	M.S. $\frac{1}{8}'' \times 1''$
Drawn by:-			Scale:- 6" = 1'-0
Traced by:-			Date:-

DETAILS OF A 3-INCH POP SAFETY VALVE



DETAILS OF SPRINGS

Part	Reqd	Description	Materials
20	1	Main Spring	Spring Steel
21	1	Compensating Spg	" "
22	2	Spring Plates	Cast Iron
23	1	Stem	M.S.-1¼"×17"
24	1	" Pin	C.R.S. 5/16"×2¼"
25	1	" Locknut	Bronze
26	1	" Nut	"
27	2	Split Pins	Brass-3/32"×½"
Drawn by:-			Scale:- 6"=1'-0"
Traced by:-			Date:-



DETAILS OF SIDE PLATES

Part	Req'd	Description	Materials
28	2	Side Plates	Cast Iron
29	2	Bolts	M.S. 1/4"×4 1/2"
Drawn by -			Scale - 6"=1'-0"
Traced by -			Date:-

QUESTIONS:

1. Make a list of the various types of bolts under the following headings:— (a) Name of bolt, (b) Where used, (c) Features.
2. Lay out on a piece of paper a helix 2" dia. 1" lead.
3. Define "lead" and "pitch" when used in reference to screw threads.
4. Make a list of the various types of pipe joints under the following headings:— (a) Name of joint, (b) Where used, (c) Features.
5. Draw a section through a "Briggs Standard" pipe thread and name the particular features of it.
6. State the differences between a "Briggs" pipe thread and a "Whitworth" pipe thread.
7. Make a list of the various types of keys under the following headings:— (a) Name of key, (b) Where used, (c) Features.
8. Make a list of the various types of lubricators stating:— (a) The name, (b) Whether suitable for grease or oil, (c) The type of mechanism it is generally used on.
9. Make a list of the various types of clutches you know of, stating:— (a) The name, (b) Positive or friction, (c) Where used.
10. Describe briefly two types of friction clutches used on hoisting drums. Illustrate your answer with simple sketches of their particular features.
11. Why is a flexible coupling used to connect a motor to a machine?
12. Sketch a section of an "Oldham" coupling.
13. Sketch in section a rubber disc coupling and a rubber cushion pin coupling.
14. What are the features of a speed reducer? Why are they used?
15. What practical applications are made of "coefficient of friction"?
16. Make a list of the various types of bearings you know of, stating:— (a) The use, (b) The particular features of each bearing.
17. What methods are used to distribute a lubricant after it enters a bearing.
18. Sketch a cross section through:—
    (a) A plain babbitt bearing, and
    (b) A ball bearing, and state the features and advantages or disadvantages of each.
19. Make a list of the various types of anti-friction bearings you are familiar with, stating the features and uses of each.
20. Show by a sketch how a bearing is made "self-aligning."
21. Show by a sketch the following features of housing seals used in anti-friction bearings:— (a) Flingers, (b) A labyrinth, (c) A grease or oil groove, (d) A felt washer.
22. Make a list of various types of valves you are familiar with, stating:— (a) Name, (b) Feature, (c) Use.
23. Write out concisely the features and function of a "Pop" safety valve.

GEAR TEETH (Lesson 1)

The purpose of this lesson is to prepare the student in definite but gradual stages to draw gears and gear teeth in an intelligent manner. The lesson has been broken up so that each point may easily be assimilated. It must be understood, however, that once a point has been dealt with, the student must carry over each stage to allow of a complete understanding of the whole problem.

Pitch circle of a gear and pinion. A small gear is called a pinion in contrast to a mating gear. Diagram 1 shows the pitch circles of a gear and pinion. These circles would represent a friction drive of two discs which under load would slip, thus showing the necessity for gear teeth to give a positive drive. The pitch circle diameters of the gear and pinion are in direct ratio to the gear and pinion ratio of 4 to 3.

The marks on the circumference of each circle represent the teeth divisions, the gear having 16 teeth, and the pinion 12 teeth, or a ratio of 4 to 3. These divisions on the circumference of the pitch circles represent a circular measure called **circular pitch** and may be found by dividing the circumference of the gear by the number of teeth in it.

The diametral pitch of a gear is a relationship, not a measurement. It represents the number of teeth in the gear per inch of pitch diameter.

Example. Gear has 16 teeth and the pitch diameter is 4″. Therefore there are 4 teeth for each inch of pitch diameter, so that the Diametral pitch (D.P.) = 4.

The Module of a gear may be found by dividing 1 by the diametral pitch.

Example. Module $= \frac{1}{DP} = \frac{1}{4}''$. This may be seen in diagram (1) on the pitch diameter, each inch division is divided into 4 parts so that the small divisions are modules.

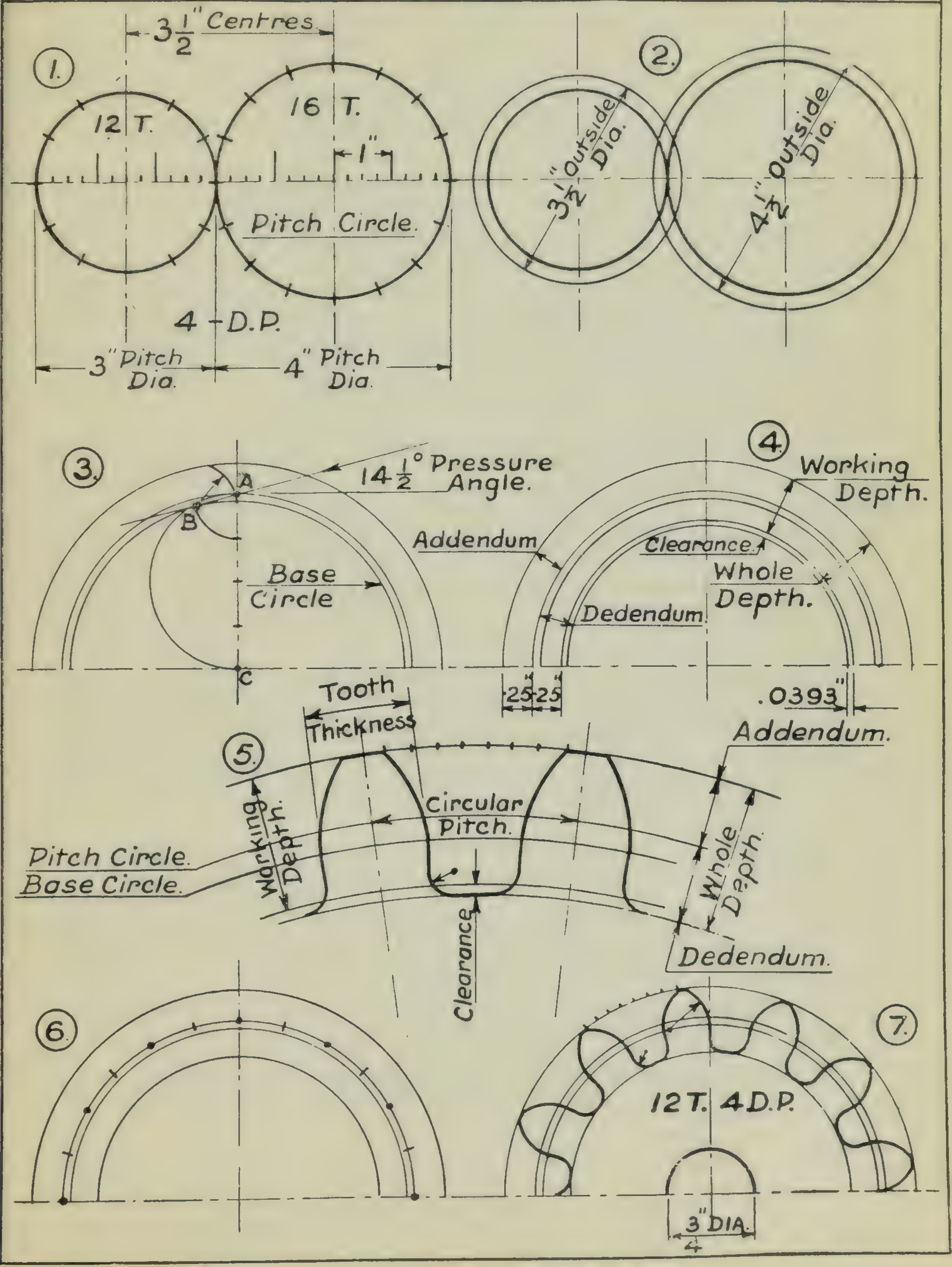
Centre distance of Gear and Pinion. This is shown from centre to centre above diagram 1. It represents one-half of the pitch diameter of the gear and pinion added together.

Example. ½ x pitch diameter of gear = ½ x 4″ = 2 ″

½ x pitch diameter of pinion = ½ x 3″ = 1½″

Centre distance **Total** = 3½″

GEAR TEETH.


①
3 1/2" Centres.
12 T.
16 T.
1"
Pitch Circle.
4 - D.P.
3" Pitch Dia.
4" Pitch Dia.
②
3 1/2" Outside Dia.
4 1/2" Outside Dia.
③
A
B
C
14 1/2° Pressure Angle.
Base Circle
④
Working Depth.
Addendum
Clearance.
Whole Depth.
Dedendum
.25"
.25"
.0393"
Addendum.
⑤
Tooth Thickness
Circular Pitch.
Working Depth.
Pitch Circle.
Base Circle.
Clearance
Whole Depth.
Dedendum.
⑥
⑦
12 T. 4 D.P.
3" DIA
4

Outside diameter of Gear and Pinion. Diagram 2 illustrates this feature. Add to the pitch circle radius an amount called the addendum which is equal to the module. If this is done the outside diameter equals the pitch diameter + 2 modules.

Example. O.D. of pinion = 3″ + 2 x ¼″ = 3½″
O.D. of gear = 4″ + 2 x ¼″ = 4½″

Note. The outside diameter of gear and pinion **does not** correspond with the ratio of the gear and pinion.

The Base Circle of a gear. The method of finding this is shown in diagram (3). The base circle is used to generate the involute curve of the face of a gear tooth and its diameter will depend upon the pressure angle of the gear teeth as will be seen later. To locate the base circle, from a point (A) on the pitch circle, draw a horizontal line and with a protractor measure an angle of 14½°, the common pressure angle used. Now describe a circle concentric with the pitch circle so that the 14½° line is tangent to it and this will be the base circle.

Approximate method of drawing the face of gear teeth with a compass. Describe a semi-circle equal in diameter to half the diameter of the pitch circle as shown. Divide the diameter of this circle into 4 equal parts. With (A) as centre and ¼ of the circle diameter as radius, describe an arc cutting the base circle at (B). With (B) as centre and (BA) as radius, describe an arc from the base circle outwards and this arc approximates the involute face of the gear tooth.

Method of locating other circles of a gear. Diagram 4 illustrates other circles which are required when drawing gear teeth. To find the **working depth** of a gear tooth one must mark off twice the addendum (or twice the module) from the outside diameter of the gear blank circle as shown in the drawing. Working depth = ¼″ + ¼″ or .25″ + .25″ = .5″.

The clearance between the mating teeth of a gear and pinion equals one-tenth of the thickness of the tooth (see diagram 5).

Note. The proportions of gear teeth are usually obtained from tables, but if they are not available, the proportions must be calculated by the student. (Table, page 183).

To find thickness of a tooth, diagram (5). This in cut gears is equal to one half the circular pitch.

To find the circular pitch. Divide the pitch circumference of a gear by the number of teeth in the gear and the answer will be the circular pitch. (See table, page 149).

Note. Thickness of teeth and circular pitch are circular measurements; they can be calculated but not easily measured. In practical work a gear tooth vernier is used to measure the chordal thickness and corrected addendum.

Example. Gear, 4″ pitch diameter, circumference = 3.1416 x 4″

Number of teeth = 16.

$$\text{Circular pitch} = \frac{3.1416 \times 4''}{16} = .7854''$$

$$\text{Thickness of tooth} = \frac{\text{circular pitch}}{2} = \frac{.7854''}{2} = .3927''$$

$$\text{Clearance} = \frac{\text{Thickness of tooth}}{10} = \frac{.3927''}{10} = .03927''$$

Now proceed to draw in the required circles in diagram 4.

To layout teeth for a circular pitch gear. Gears are made either on a Diametral pitch basis or a Circular pitch basis. Always mention "inches" for Circular pitch but not for Diametral pitch.

4″ C.P. means 4″ Circular pitch.
4 D.P. means 4 Diametral pitch. (See table, page 149.)

Draw the diagram 5 as shown making the circular pitch 1¾″. The gear has 25 teeth and 13.93″ pitch diameter.

First draw the pitch circle 6.96″ radius, and on it mark off the circular pitch by stepping off chords ¼″ each, 7 times with a pair of dividers to approximate the 1¾″ circular measure representing circular pitch. Mark off the thickness of the teeth and draw the other circles as previously explained. Draw the curves representing the involute faces of the teeth as shown in diagram 3. Join the curves at the base circle with radial lines from the centre of the gear. Now divide the space between the gear teeth on the addendum circle (outside diameter circle) into 7 equal parts with a pair of dividers; this will give you the radius of the fillet which joins the radial flank to the bottom of the tooth space. See Grant's Odontograph for laying out circular pitch teeth on cast gears (page 182).

Diagram 6 shows the circular pitches laid out with dots and the thickness of the teeth with dashes in preparation for the gear teeth in diagram 7.

Diagram 7 shows the gear teeth complete, scale full size. This gear was started in diagram 3 and continued in diagrams 4 and 6. This gear represents the smallest number of teeth usually cut on a spur gear and shows the undercutting of the teeth which of course has a weakening effect. Methods of overcoming this feature will be dealt with in the next lesson.

Exercise.

On a 9″x12″ piece of paper draw the diagrams shown according to instructions given in this lesson. Diagrams 1 and 2 half full size. Diagrams 3 to 7 full size.

GEAR TEETH (Lesson 2)

The involute gear tooth is a **single curve tooth** and is the system mostly used. Another system used for some time but now being discarded is the double curve tooth known as the Cycloidal System.

The cycloidal gear tooth is generated by a circle rolling around the pitch circle. A curve called the **Epi-cycloid** may be obtained by rolling a generating circle on the pitch circle but outside of it. A point on such a generating circle if traced in its movement would develop the Epi-cycloid curve used for the face of the gear tooth. Similarly another generating circle rolling inside the pitch circle would trace the hypo-cycloid curve used for the flank of the tooth.

How to draw an involute tooth face. Diagram 1 shows the method used for obtaining an involute curve for a 14½° pressure angle on a standard 12 tooth pinion, 4D.P. The diagram is drawn twice full size and represents the same pinion already drawn in the last diagram sheet.

Method. After drawing the pitch circle, base circle, addendum and dedendum circles, step off with dividers a series of small divisions on the base circle. Number these points as shown. Mark off the circular pitch and thickness of the teeth on the pitch circle. Draw radial lines from the numbered points on the base circle. Draw lines at right angles to each numbered radial line and tangent to the base circle. Number each tangent on the addendum circle as shown.

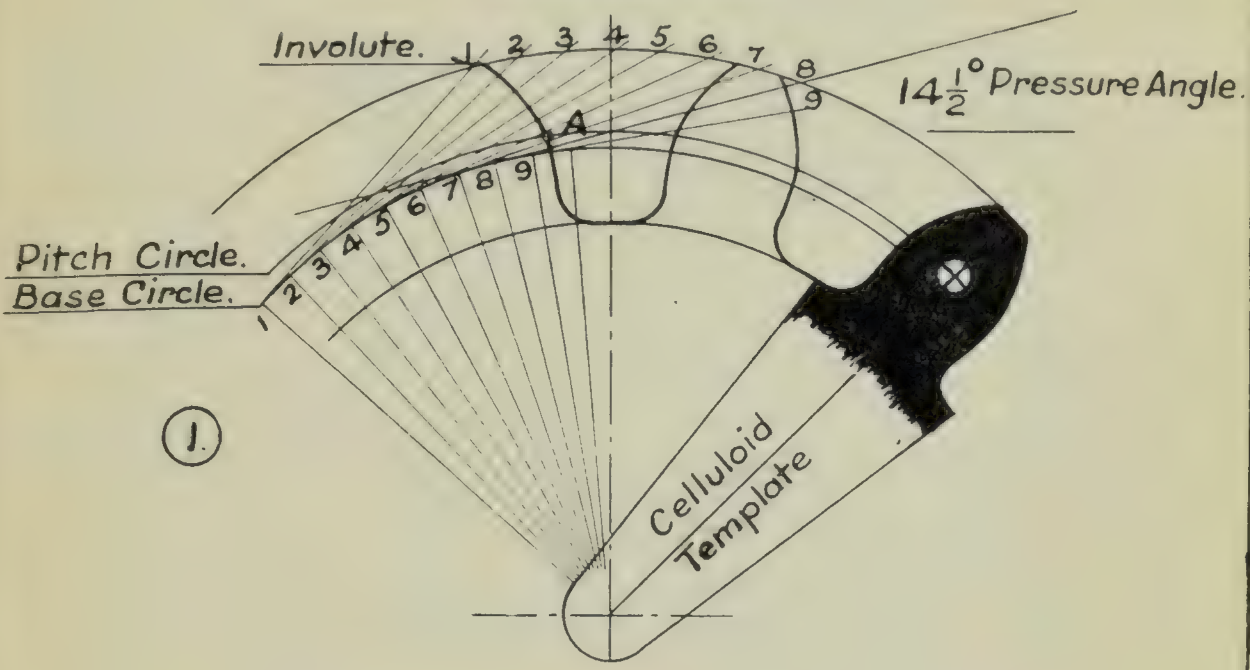
Note that the thickness of the tooth at point (A) is located between tangent lines (6) and (7). With (6) on the base circle as centre, and (6A) as radius draw an arc forming approximately part of the involute of the tooth face between lines (6) and (7). Then with (5) as centre and a radius to join the arc previously made, draw an arc between line (5) and line (6). Proceed in the same manner with all other divisions until the curve is drawn from the base circle to the addendum circle. Draw the flank and fillet as explained in the previous lesson.

Drawing gear teeth with a celluloid template. Scratch a centre line on a strip of celluloid, put a pin through the centre line and the centre of the gear. Now rotate the template until it covers the tooth outline already laid out. Scribe the tooth outline and cut out with scissors, and smooth the edge of the celluloid with abrasive cloth wrapped around a round pen handle for finishing the fillet. Check the template until it fits the tooth face perfectly. Loosen the template and reverse it. Mark off the thickness of the tooth and scribe the second tooth face curve, finish as before. Mark all tooth curves by using the template, with its centre line on all circular pitch points.

Note. When using ink to trace the tooth outlines, place a thin set square beneath the template to raise it slightly from the tracing paper or cloth, otherwise the ink will run and spoil your drawing. See lesson on "Representing threads with Helical Lines" (page 94).

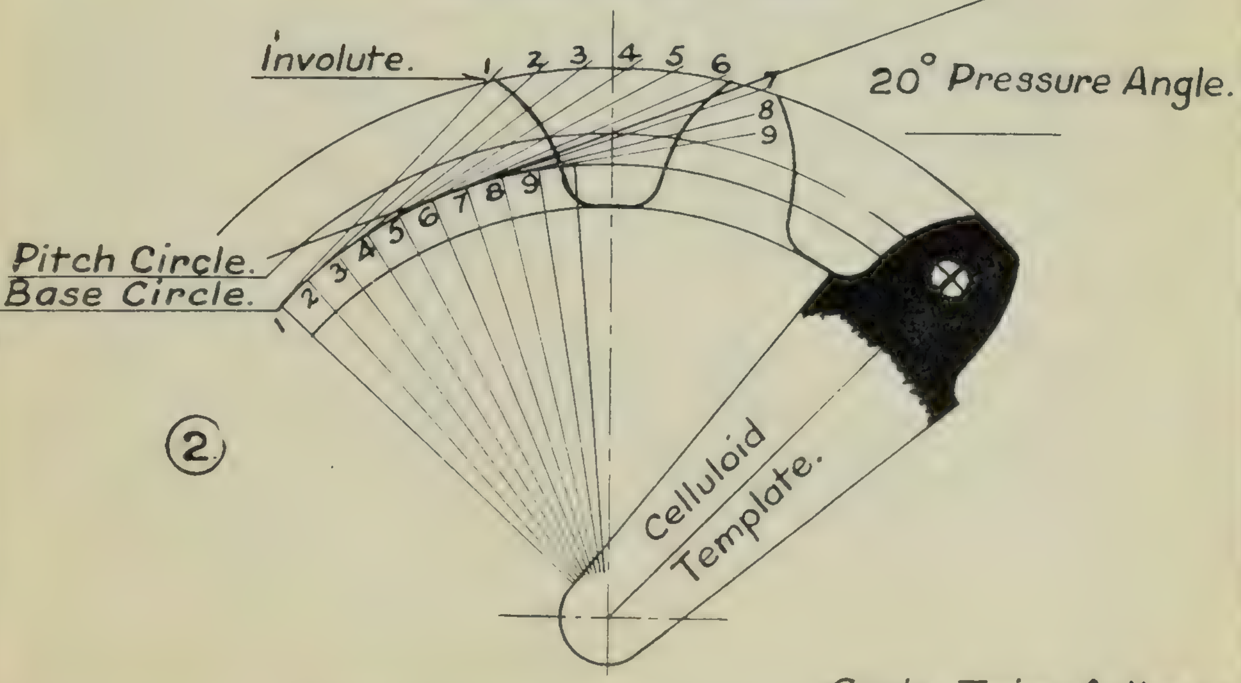
GEAR TEETH.

12T. PINION 4 D.P.



STUB TOOTH.

12T. PINION 4/5 D.P.



Scale. Twice full size.

Drawing a 4/5 stub tooth. 12 teeth. The stub tooth shown in diagram 2 is a strong tooth compared to the standard 14½° pressure angle tooth shown in diagram 1.

Standard involute pinions of 12 teeth have teeth that are weakened by the undercutting during the tooth generation. Diagram 2 shows a tooth with no undercutting.

The circular pitch and thickness of the teeth are the same in the stub tooth pinion diagram 2 as the standard 14½° pinion diagram 1. Draw the pitch circle in diagram 2 the same diameter as in diagram 1 and mark off the circular pitch and thickness of tooth on the pitch line in the same manner as for a 4D.P. pinion.

The addendum and dedendum in the stub tooth is made for a 5D.P. pinion. This amount can be obtained from a gear tooth part table, page 183, or worked out as explained in the previous lesson with the exception of the clearance. Module and addendum (0.200″), working depth (0.400″). For stub gear teeth as made by Fellows Gear Shaper Co. system, the clearance is made greater than in the ordinary gear systems and equals 0.25 divided by the denominator of the diametral pitch as follows: $4/5\text{D.P.} = \frac{0.25}{5} = 0.05''$.

Your calculations should now work out as follows:—

Proportions for 4/5 Diametral Pitch

Thickness of tooth	= 0.3927″
Addendum	= 0.2000″
Working depth	= 0.4000″
Depth below pitch line	= 0.2500″
Clearance	= 0.0500″
Whole depth	= 0.4500″

Now draw the addendum circle to give the outside diameter of the pinion in diagram 2. Note that the outside diameter in diagram 2 is less than the outside diameter of the pinion in diagram 1. Measure the full depth of the tooth and draw the dedendum circle which you will observe is larger in diameter than that in diagram 1.

Layout the involute with a 20° pressure angle in a similar way to diagram 1. Make the template and finish the drawing of the teeth.

Machining gear teeth. Formed cutters, 8 to each diametral pitch, are used for the milling standard involute teeth, while 15 cutters are recommended for milling stub tooth gears.

When a generating machine such as the Fellows Gear Shaper is used, one cutter is required for each pitch.

Exercise.

On a 9″x12″ piece of paper draw two half gears as specified in diagrams 1 and 2 with templates. Scale twice full size.

TABLES SHOWING CORRESPONDING CIRCULAR AND DIAMETRAL PITCHES

Table No. 1 shows the diametral pitches with the corresponding circular pitches.

Table No. 2 shows the circular pitches with the corresponding diametral pitches.

Table No. 1

Diametral Pitch	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches
1¼	2.5133	11	.286
1½	2.0944	12	.262
1¾	1.7952	14	.224
2	1.571	16	.196
2¼	1.396	18	.175
2½	1.257	20	.157
2¾	1.142	22	.143
3	1.047	24	.131
3½	.898	26	.121
4	.785	28	.112
5	.628	30	.105
6	.524	32	.098
7	.449	36	.087
8	.393	40	.079
9	.349	48	.065
10	.314		

Table No. 2

Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches	Diametral Pitch
2	1.571	¾	4.189
1 ⅞	1.676	11/16	4.570
1 ¾	1.795	⅝	5.027
1 ⅝	1.933	9/16	5.585
1 ½	2.094	½	6.283
1 7/16	2.185	7/16	7.181
1 ⅜	2.285	⅜	8.378
1 5/16	2.394	5/16	10.053
1 ¼	2.513	¼	12.566
1 3/16	2.646	3/16	16.755
1 ⅛	2.793	⅛	25.133
1 1/16	2.957	1/16	50.266
1	3.142		
15/16	3.351		
⅞	3.590		
13/16	3.867		

GEAR TEETH (Lesson 3)

Drawing a pinion and gear in mesh. The diagram shows a part of a standard 14½° pressure angle involute pinion and gear in mesh. From your previous experience draw full size part of the pinion and gear. Calculate the diameters for each and work out all the proportions of the teeth. Point B is the centre of a gear tooth and also represents the meeting place of the two pitch circles. The pressure angle is 14½° and the pressure line is a common tangent to the base circle of the pinion and the gear. B C represents the radius of the arc for forming the face of the gear teeth and A B represents the radius of the arc for forming the face of the pinion teeth.

At the bottom of your drawing make a detailed list of the gear proportions you have calculated as follows:

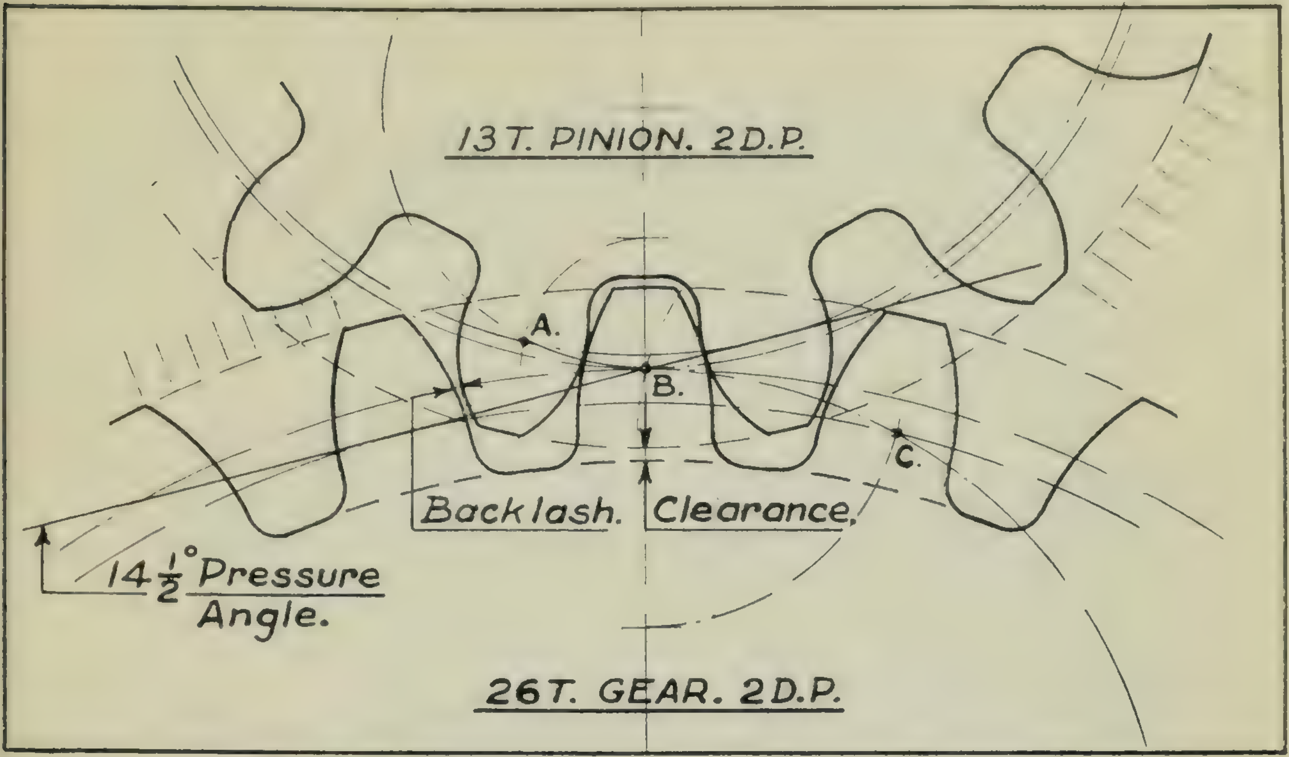
Proportions

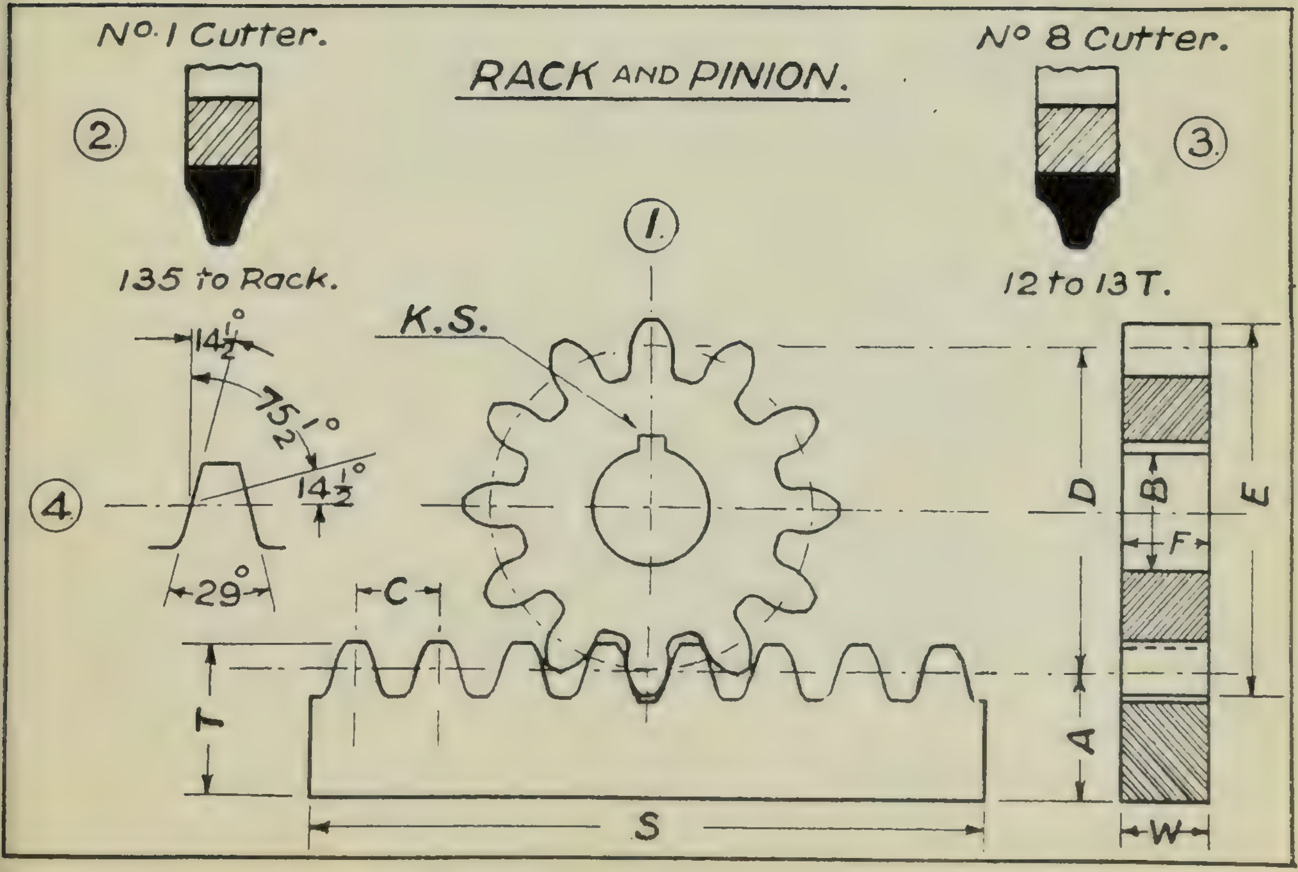
	Gear	**Pinion**
1. Diametral pitch..................	2	2
2. Number of teeth................	26	13
3. Pitch diameter....................		
4. Module and addendum......		
5. Working depth....................		
6. Circular pitch.......................		
7. Thickness of tooth............		
8. Clearance................................		
9. Whole depth of tooth.......		
10. Outside diameter................		

Note. This lesson is really a test to see if you have grasped the principles laid down in "Gear Teeth" lessons 1 and 2.

Exercise.

Lay out on a 9″ x 12″ sheet the work as described above.


13T. PINION. 2D.P.
A.
B.
C.
Backlash.
Clearance.
14½° Pressure Angle.
26T. GEAR. 2D.P.


No. 1 Cutter.
RACK AND PINION.
No 8 Cutter.
②
③
①
135 to Rack.
12 to 13 T.
K.S.
14½°
75½°
14½
④
29°
C
D
B
E
F
T
A
S
W

RACK AND PINION

Function of Rack and Pinion.

Diagram 1, page 151, shows a 12 T pinion in mesh with a rack. If the pinion rotates on a fixed spindle the rack would be forced to be moved just as it is applied to a drill press spindle to operate the feed. If the rack is stationary and the pinion rotates, then the pinion moves with its axis moving parallel to the rack as it is used on a lathe apron mechanism.

Cutters for rack and pinion are shown in diagrams 2 and 3. These cutters are used for milling the teeth and show the difference in form for the two extremes. A rack tooth is shown in diagram 4 for a 14½° pressure angle. Because the cutter in diagram 2 is used to cut from 135 teeth to a rack, the rack teeth in diagram 1 are shown curved above the pitch line.

Ordering a Rack and Pinion.

Make a sketch as shown on page 151 and provide the information as given in the diagram and listed as follows:—

RACK

Pitch
  Circular = C
  Diametral = $\frac{C}{3.1416}$
Thickness = T
Face = W
Length of Rack = S.
Material =
Pitch line to bottom of rack = A.

PINION

Pitch
  Circular = C
  Diametral =
Number of Teeth =
Pitch Diameter = D
Outside Diameter = E
Bore = B
Face = F
Key Seat = K.S.
Material =

Exercises.

1. On a 9″x12″ piece of paper draw a rack and pinion as shown. Pinion 12 T., 3 D.P., Bore 1″, Face 1″, length of rack 8″, thickness 1¼″.

2. On a piece of paper make a tabulated order for the rack and pinion you have drawn.

DESIGNING A SPUR GEAR TO FIT A GIVEN PINION

Problem.

Assume that a workman gives you a pinion and asks you to work out all proportions and make a working drawing of a gear to mate with the pinion, to give a ratio of 2 to 1.

Procedure.

1. Measure the outside diameter of the pinion with a micrometer or vernier caliper exact to 0.001″.

2. Count the number of teeth in the pinion.

3. Find the number of teeth in the gear by multiplying the pinion number by the ratio.

4. Find the diametral pitch of the gear and pinion.

5. Find all other proportions and tabulate as shown in example.

Note. Ratio of a gear and pinion will coincide with the number of teeth and the pitch diameters, but NOT the outside diameters.

HOW TO MEASURE A GIVEN GEAR OR PINION

1. Gears with an even number of teeth.

Small gears with an even number of teeth can be measured for outside diameter with a Vernier Caliper or outside Micrometer of convenient size, to a 0.001″ limit size for **cut gears.**

Cast gears may be measured with a pair of outside calipers or a rule.

2. Gears with an odd number of teeth.

It is impossible to measure the outside diameter of such gears direct because a tooth is diametrically opposite a space between two teeth. The methods of obtaining the outside diameter will vary with the size of the gear and its diametral pitch.

Method (A). When the space between the teeth is small, wrap a flexible steel rule around the outside of the gear. Measure the outside diameter of the gear plus the thickness of the rule on one side. Measure the thickness of the rule with a micrometer and subtract it from the dimension first measured. The remainder is the outside diameter of the gear.

Method (B). Measure the distance from the bore to the outside of a tooth on the rim, multiply this by two and add to it the bore diameter. The total will be the outside diameter of the gear.

DESIGNING A SPUR GEAR TO FIT A GIVEN PINION

NAME OF PART	Symbol	Formula	Calculation	Answer
Outside diameter of pinion	**D**		Measure	3.000″
Number of teeth in pinion			Count	22
Number of teeth in gear	**N**	Ratio 2 to 1	$= 22 \times 2$	44
Diametral pitch of pinion and gear	**P**	$\frac{N+2}{D}$	$= \frac{22+2}{3} = \frac{24}{3}$	8

GEAR PROPORTIONS

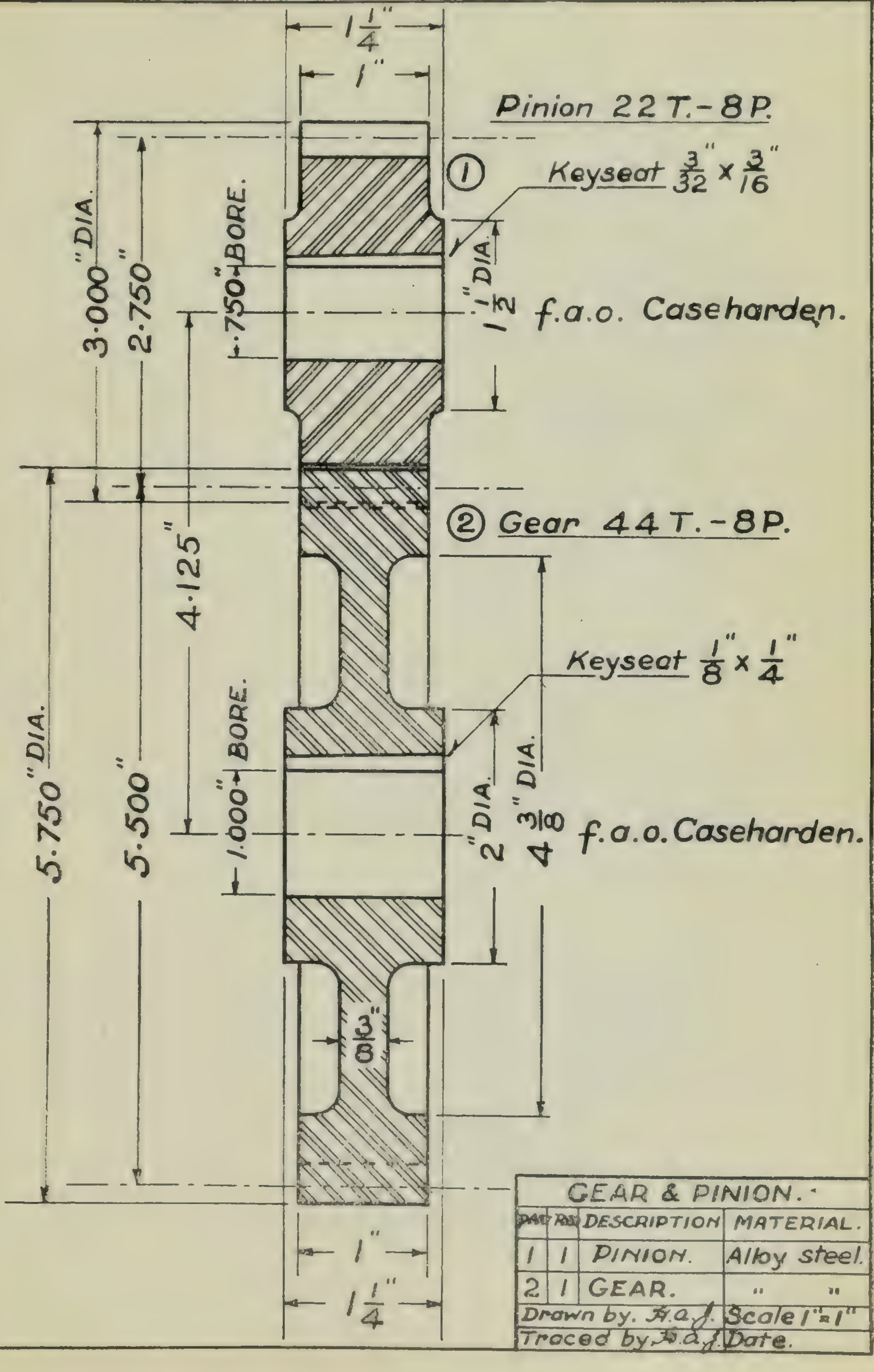
Outside diameter of gear	**D**	$\frac{N+2}{P}$	$= \frac{44+2}{8} = \frac{46}{8}$	= 5.750″
Circular pitch	**P′**	$\frac{3.1416}{P}$	$= \frac{3.1416}{8}$	= 0.3927″
Thickness of tooth	**t**	$\frac{1.5708}{P}$	$= \frac{1.5708}{8}$	= 0.1963″
Addendum	**S**	$\frac{1}{P}$	$= \frac{1}{8}$	$\frac{1''}{8}$
Working depth	**D″**	$\frac{2}{P}$	$= \frac{2}{8}$	$\frac{1''}{4}$
Clearance	**f**	$\frac{t}{10}$	$= \frac{0.1963''}{10}$	= 0.0196″
Dedendum		s+f	$= \frac{1}{8}+0.0196''$	= 0.1446″
Whole depth of tooth		D″+f	$= \frac{1}{4}+0.0196''$	= 0.2696″
Pitch diameter	**D′**	$\frac{N}{P}$	$= \frac{44}{8}$	= 5.500″
Centre distance of pinion and gear		$\frac{\text{D′ of gr.}}{2} + \frac{\text{D′ of pn.}}{2}$	$= \frac{5.5''}{2} + \frac{2.750''}{2}$	= 4.125″

Exercises.

1. Given a pinion with an outside diameter of 3″ and 16 teeth. Work out the proportions of a gear to mate with it to give a 2 to 1 ratio. Tabulate your work as shown in example given.

2. Make a working drawing of the gear and pinion that you worked out in question 1. Scale full size. Make the bore, hub, and thickness the same as the gear and pinion illustrated.

DESIGNING A GEAR.



GEAR & PINION.

[illegible]	[illegible]	DESCRIPTION	MATERIAL.
1	1	PINION.	Alloy steel.
2	1	GEAR.	" "
Drawn by. H.a.J.			Scale 1" = 1"
Traced by. H.a.J.			Date.

DESIGNING A GEAR WHEEL

The Spur Gear wheel proportions shown opposite are intended as a guide in designing Spur Gears. They indicate the pattern proportions which are based on the diametral pitch of the gear being designed. Three types of gears are shown. The partial elevation and sectional elevation on the left show a gear wheel with six spokes which are elliptical in section. The thickness of the rim recommended is $\frac{4}{\text{d p}}$. This is a minimum requirement and may be increased if necessary. The hub extension (H) may be made to suit particular requirements. As these sizes given are pattern sizes, a keyseat is not shown, but it would be cut in line with the centre of one of the spokes which is the strongest part. Sometimes a special boss is cast on the hub to receive a keyseat.

Method of finding measurements for a given gear. A 2 D. P. gear with 30 teeth is required to be drawn.

$$\text{Rim thickness} = \frac{4}{\text{DP}} = \frac{4}{2} = 2''$$

$$\text{Width of spoke W} = \frac{5 + \frac{\text{Teeth}}{40}}{\text{DP}} = \frac{5 + \frac{30}{40}}{2} = \frac{5\,\frac{3}{4}}{2} = 2\,\frac{7}{8}''$$

All other dimensions may now be obtained from specifications or given data. (See also pages 77 and 78).

Part of a ribbed spoked gear is shown in the upper right-hand diagram. The section shows how the spokes are stiffened by ribs on both sides of the spokes.

The lower right-hand diagram shows spokes that have an I-Beam section for gears carrying a heavy load.

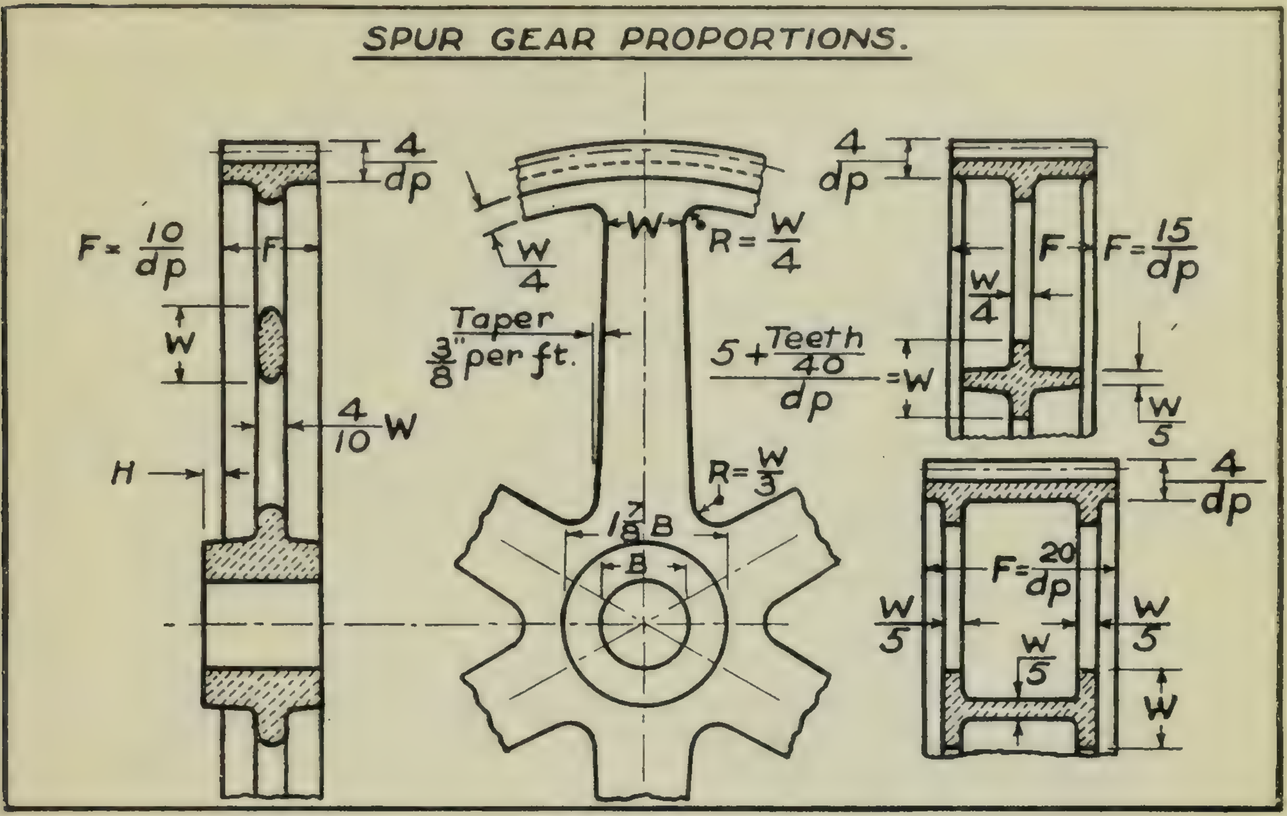
Exercises.

1. On a 9″ x 12″ piece of paper draw, scale full size, a front elevation and a sectional elevation of a spur gear 3 D. P., 20 teeth, 7.333″ outside diameter, bore 1″, 6 spokes, elliptical section.

2. On a 9″ x12″ piece of paper draw, scale half full size, a front elevation and a sectional elevation of a spur gear, bore 1″, 4 D. P., 48 teeth, 12.500″ outside diameter, with 6 ribbed spokes as shown on the upper right diagram.

3. On a 9″ x 12″ piece of paper draw, scale half full size, a front elevation and a sectional elevation of a spur gear with 6 spokes for heavy duty with I-Beam section, as shown on the lower right-hand diagram, 3 D. P., 42 teeth, 14.000″ outside diameter, 1½″ bore.

Note. Show keyseats cut in questions 1, 2 and 3. Your previous knowledge of keys and keyways should enable you to do this.



Recommendations for gear users.

1. Do not use cast iron for a pinion because, as you have already observed from previous lessons, a pinion tooth is weaker than a gear tooth of the same metal. Use a tougher material for the pinion.

2. Use cut gears if possible. Gears with cast teeth are only suitable for slow speed and rough service.

3. A rawhide pinion should not be used if it may come in contact with water or oil. For damp or oily locations use a celeron pinion, noted for unusual strength, resiliency and toughness.

Celeron is impervious to heat, oil, water and most chemicals. Celeron is made of woven fabric impregnated with a synthetic resin and bonded at high temperature under great pressure.

4. Use bronze for gears rather than brass, for a little extra cost the bronze is twice as good.

5. Do not run two soft, low carbon steel gears together. Use a harder steel or a case-hardened gear, or a different metal in each gear.

SKETCHING AND ORDERING BEVEL GEARS

It is not the intention of this lesson to go into the details of the design of gears, but rather to give the student sufficient ability to be able to sketch from memory, and make out an intelligent order for the gears required. Sketches may be prepared while equipment is in use, and as soon as it has stopped, dimensions and other particulars may be added to the sketches already prepared. With your background of spur gear design you should be able to readily absorb the following sketch lessons.

Bevel Gears are usually used to connect two shafts whose axes lie in the same plane and if produced would intersect. The shafts are usually at right angles, but if they are not they are called angular bevels, but the same general principles apply to both.

Mitre Gears are bevel gears of a ratio of one to one with a 45 degree pitch angle.

A Crown Gear is one with a pitch angle of 90 degrees or a flat gear, but other gears of high ratio and consequent large pitch angle have been called crown gears.

Backing. The draftsman usually shows backing from the pitch line to the face of the hub as shown in diagram 4. This is of no practical use to the lathe hand if put on a working drawing as he must have the greatest diameter of the gear. Your order sketch shown would be converted by the manufacturer.

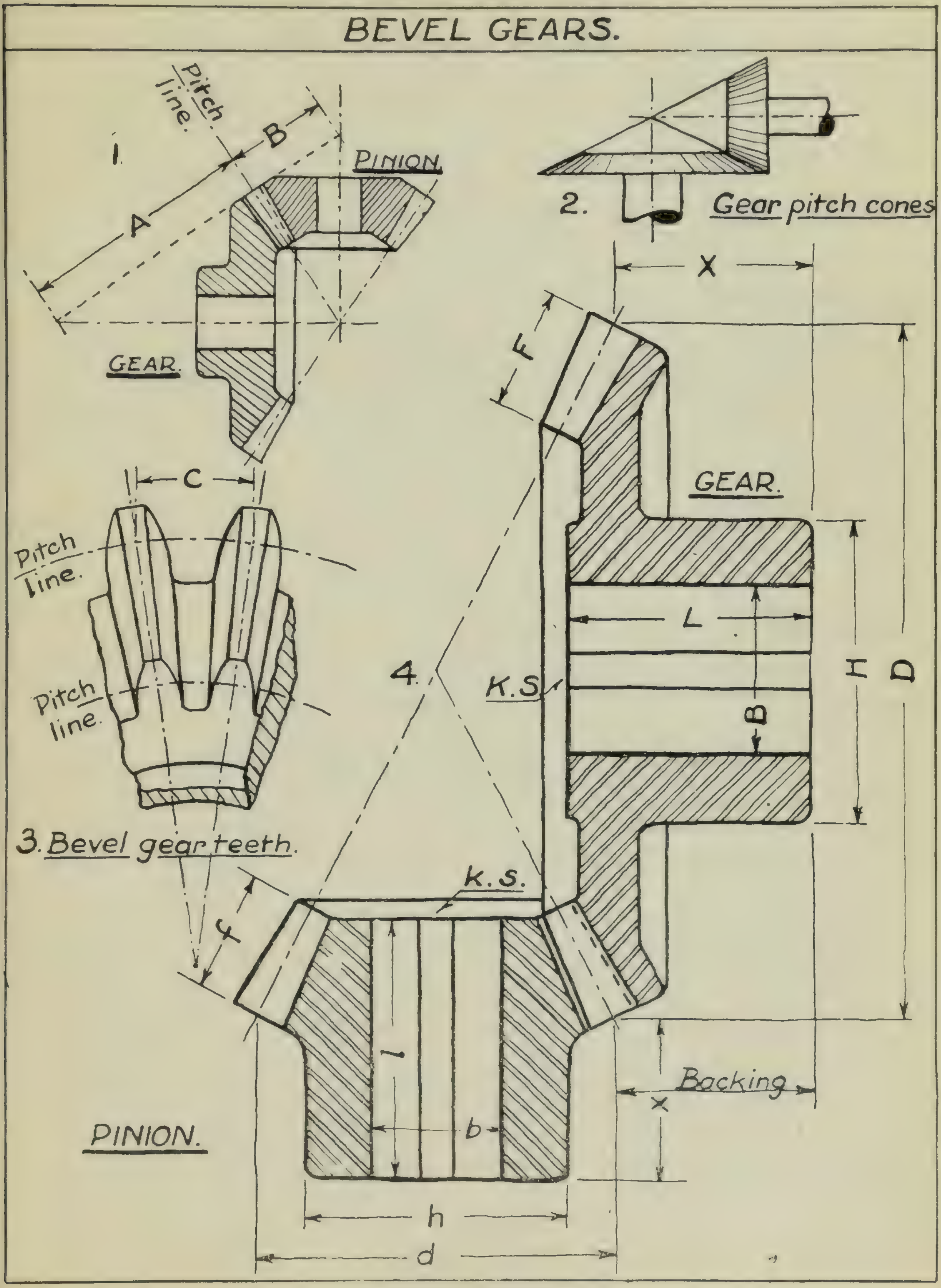
A Bevel Gear compared to Spur Gear. Diagram 1 shows (A), the back cone radius of the bevel gear, and (B), the back cone radius of the bevel pinion. This is equal to the radius of a spur gear, with similar tooth proportions. The pitch and pitch diameter of a bevel gear or pinion is always that at the large end of the teeth.

Gear Pitch Cones, diagram 2. Show how the teeth of bevel gears are formed about the frustrum of cones whose apexes are at the same point where the axes of the shafts meet.

The cones are called pitch cones because they roll on each other, and because the teeth are pitched upon them.

Bevel gear teeth are shown in diagram 3 showing how the teeth taper off from the outside of the gear towards the centre. The tooth proportions are based on the outside pitch line where circular pitch is indicated by (C).

Mating gear and pinion. When ordering either a gear or pinion separately the number of the teeth in the mating gear or pinion must be stated.



Freehand Sketches

Rules for Ordering Bevel Gears

Gear.				Pinion.			
Number of Teeth		=		Number of Teeth		=	
Pitch	Circular	=	C	Pitch	Circular	=	c
	Diametral	=			Diametral	=	
Face		=	F	Face		=	f
Bore		=	B	Bore		=	b
Pitch Diameter		=	D	Pitch Diameter		=	d
Backing		=	X	Backing		=	x
Length Through Hub		=	L	Length Through Hub		=	l
Diameter of Hub		=	H	Diameter of Hub		=	h
Key Seat		=	K.S.	Key Seat		=	k.s.
Material		=		Material		=	

Exercises.

1. On a 9″ x 12″ piece of paper sketch freehand the diagrams shown.

2. On a 9″x12″ piece of paper sketch freehand a pair of mitre gears and tabulate ordering information below the sketch.

HELICAL AND HERRINGBONE GEARS

Helical gears are often called "spiral gears," but this term is not correct although it is commonly used. A "Helix" is a path making regular progress around a cylinder. A "Spiral" is a path making progress around a cone.

Helical gears are used to connect shafts in the following manner:

(1.) Parallel shafts as shown in diagram 1.

(2.) Shafts at right angles and not intersecting as shown in the following lesson, (page 165).

(3.) Shafts inclined at any angle and not intersecting.

The teeth of a helical gear are cut at what is known as the helix angle shown at (a) in diagram 1. If this helix were completed around the cylinder the diameter of which is the pitch circle shown at (D), the amount it progressed parallel to the axis in one revolution would be called the "lead" of the helix.

The teeth, therefore, are not cut in a straight line as they appear to be, but follow a helical curve around the cylinder of which the gear is a segment.

The helical gear shown in diagram 1 performs much the same functions as a spur gear, but has several advantages as compared to spur gears as follow:—

(1.) Greater strength, because there are more teeth in mesh at one time, with the load more widely distributed.

(2.) They are much quieter and smoother in operation than spur gears, because back lash, vibrations and sudden shocks to the tooth faces are largely eliminated.

(3.) There is one important objection to helical gears and that is caused by the direction of the force acting on the teeth faces which gives end thrust. The end thrust is in proportion to the angle of the teeth.

Single helical gears are usually cut with the helix angle at 15° or 7°, and thrust bearings used for the larger angle teeth.

Right and left-hand helical gears. To decide this you are advised to adopt the method given on pages 67, 69 on threads. Place the axis of the gear in a vertical position. If the teeth then incline to your right they are right-hand; if to the left, they are left-hand.

Note. For parallel shafts a right-hand gear mates with a left-hand gear.

Double Helical or Herringbone Gears. Diagram 2 shows this type of gear and pinion in mesh. The teeth are generated to true involute form and lie at an angle of 23° or 30° for modern gear generating machines. One-half the teeth are right-hand and one-half are left-hand. This gear automatically overcomes the end thrust objection of a single helical gear and has the following advantages:—

(1.) The action of the gear teeth is continuous, smooth and noiseless.

(2.) Great strength because of the double-angle tooth formation.

(3.) Back lash and vibration practically eliminated.
(4.) Great power may be transmitted through comparatively small gears.
(5.) Elimination of end thrust because of the double helix angle of the teeth.

ORDERING INFORMATION for HELICAL GEARS

Send sketch as shown in diagram 1, and details as follows:—

Gear.			**Pinion.**		
Number of Teeth	=		Number of Teeth	=	
Pitch Circular	=	Pc	Pitch Circular	=	Pc
Diametral	=		Diametral	=	
Normal Circular Pitch	=	Pn	Normal Circular Pitch	=	Pn
Face	=	F	Face	=	f
Bore	=	B	Bore	=	b
Pitch Diameter	=	D	Pitch Diameter	=	d
Outside Diameter	=	O	Outside Diameter	=	o
Length of Hub	=	L	Length of Hub	=	l
Key Seat	=	K.S.	Key Seat	=	k.s.
Helix Angle	=	a	Helix Angle	=	a
Material			Material		

Centre Distance = C

ORDERING INFORMATION for HERRINGBONE GEARS

Send sketch as shown in diagram 2 and details as follows:—

Gear			**Pinion.**		
Number of Teeth	=		Number of Teeth	=	
Circular Pitch	=	Pc	Circular Pitch	=	Pc
Normal Circular Pitch	=	Pn	Normal Circular Pitch	=	Pn
Face	=	F	Face	=	f
Bore	=	B	Bore	=	b
Pitch Diameter	=	D	Pitch Diameter	=	d
Outside Diameter	=	O	Outside Diameter	=	o
Length of Hub	=	L	Length of Hub	=	l
Key Seat	=	K.S.	Key Seat	=	k.s.
Material			Material		

Centre Distance = C
Helix angle usually 30° on gear and pinion

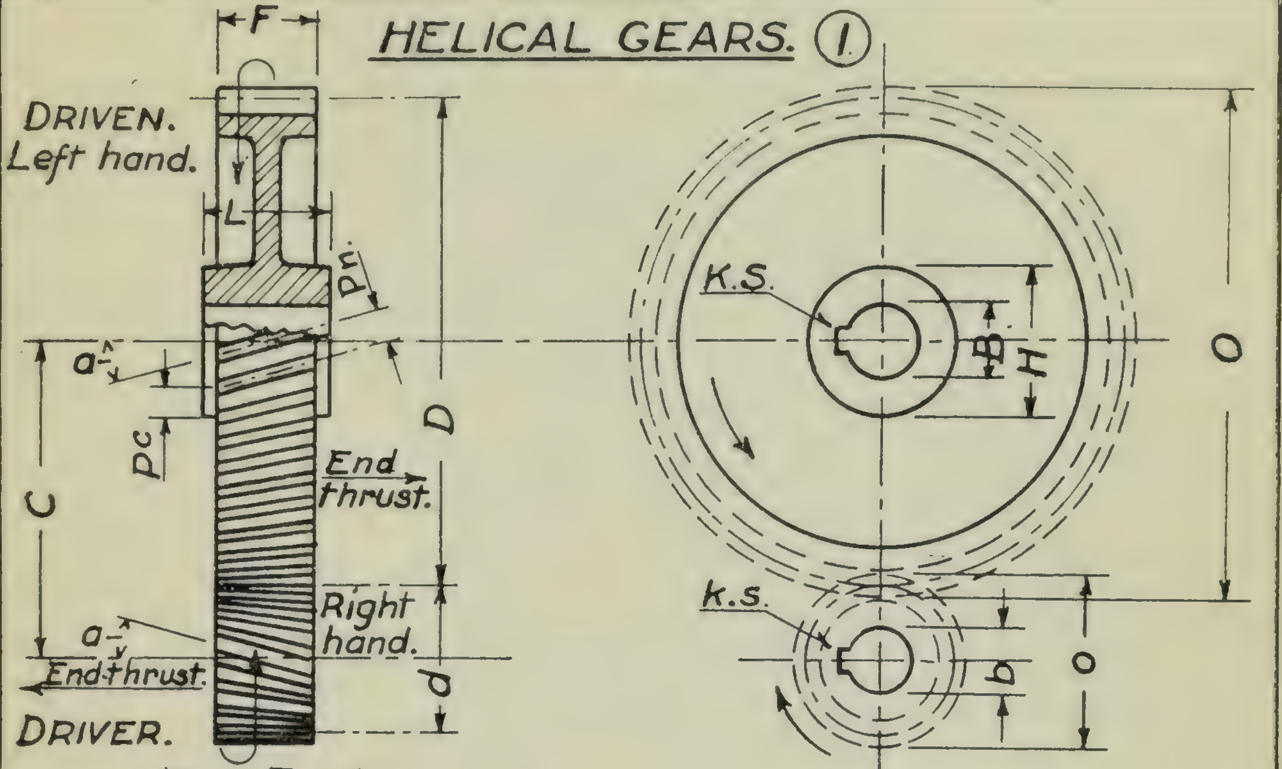
Exercises.

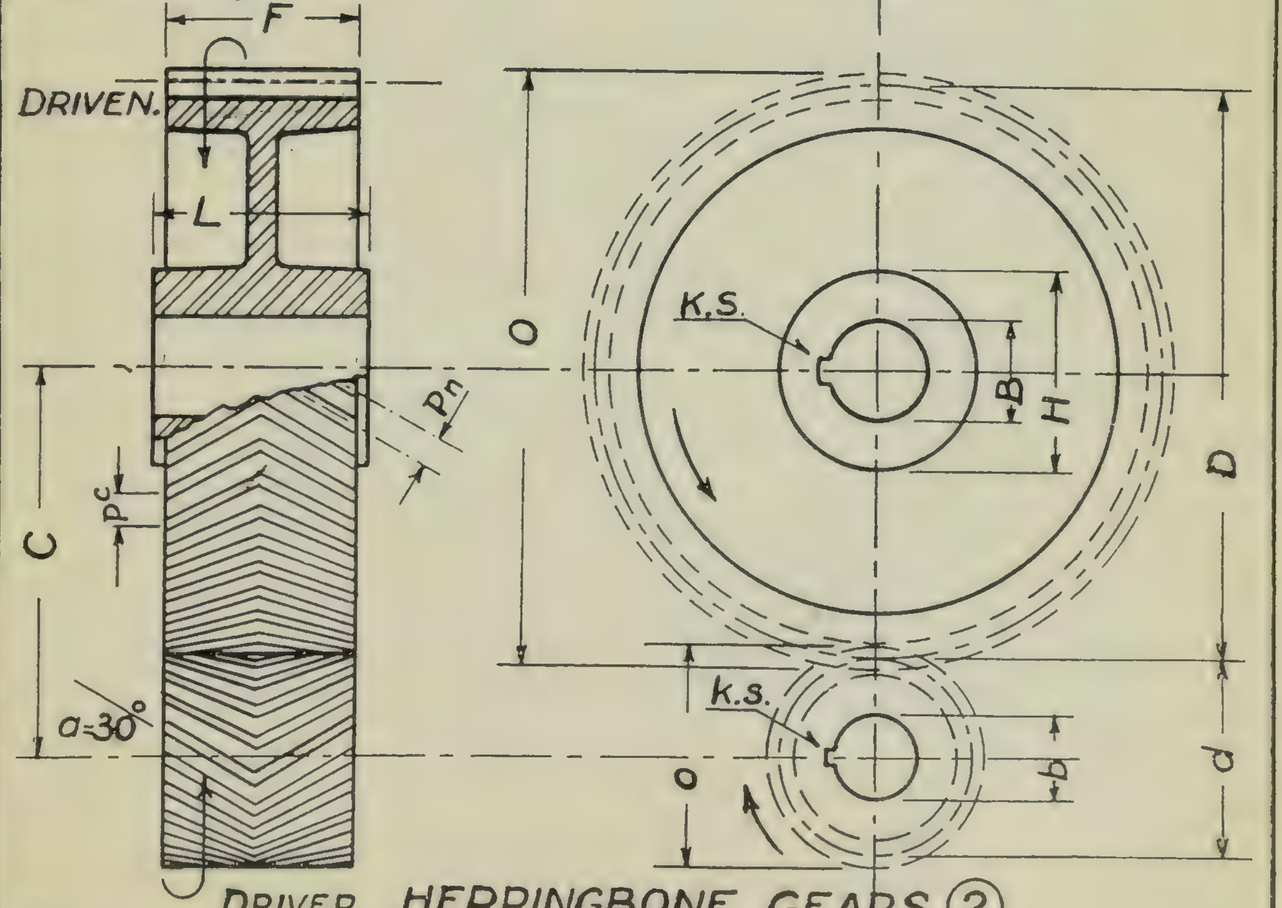
1. On a 9″x12″ piece of drawing paper make a sketch of the Helical and Herringbone Gears as shown.

2. Write out a list for ordering a Helical gear and Pinion and a Herringbone gear and Pinion.

GEARS.

HELICAL GEARS. ①





HERRINGBONE GEARS. ②

WORM AND SPIRAL OR HELICAL GEARS

Worm gearing consists of two parts, a worm as shown separately in diagram 1, and a worm gear as shown in mesh with the worm in diagram 2.

The worm is cylindrical in form and is threaded. The thread may be single or multiple, depending upon its use. With a single threaded worm as shown in diagram 1, the worm gear will rotate an amount equal to the circular pitch of the worm, shown at (C), diagram 1, for one revolution of the worm. For a double-threaded worm the gear would rotate an amount equal to twice the circular pitch for each revolution of the worm. The lead of a double-threaded worm is twice that of a single-threaded worm of the same pitch.

If a worm with a single thread were used with a worm gear having 30 teeth, the reduction ratio would be 30 to 1, but if a double-thread worm were used, the reduction would be 15 to 1. The worm gear is similar to a spiral gear for transmitting power at right angles.

Features of worm gearing.

(1.) Smooth action and great reduction in velocity.

(2.) When a great increase in effective power or torque is required.

(3.) They are subject to considerable heating and abrasion, therefore proper lubrication is essential, and should be enclosed and run in a bath of oil.

(4.) A thrust bearing is desirable in a worm gear mounting.

(5.) Worms are usually made of steel and case-hardened while a worm gear is made of bronze or high test cast iron.

(6.) Pitch of worms and wheels are based on circular or lineal pitch. Diametral pitch is not used.

(7.) Angle of thread 29° or 14½° pressure angle for single and double threads and 20° pressure angle for triple and quadruple threads.

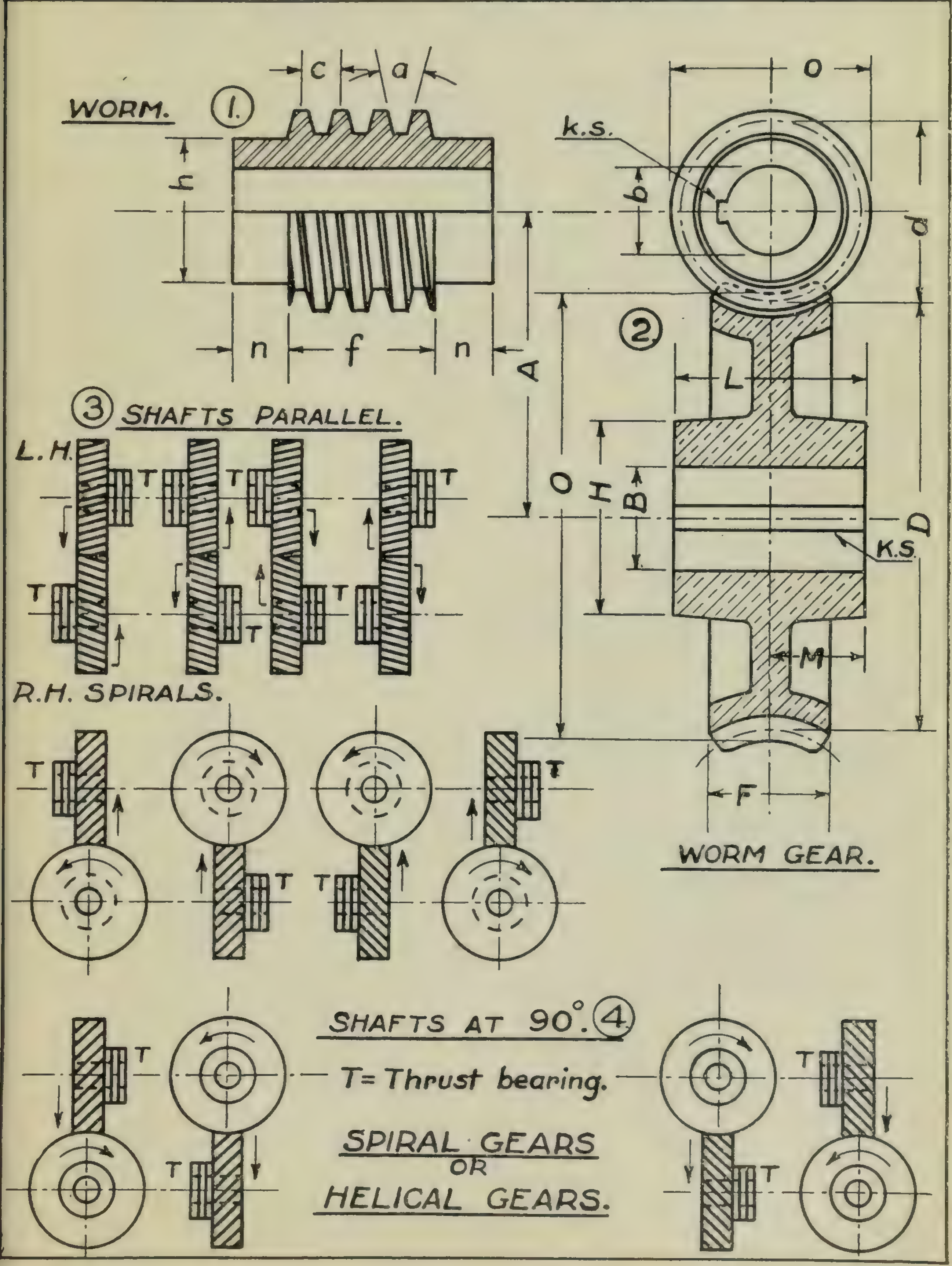
(8.) Three types of worm gears are used ;

  (a) A straight faced type which is practically a helical gear.

  (b) The Hobbed Straight Face type used for light loads.

  (c) The Concave Face, the most efficient type, as shown in diagram 2, and the generally accepted standard form.

WORM AND SPIRAL GEARS.



ORDERING INFORMATION for WORM AND WORM GEARS

Send sketch as shown in diagrams 1 and 2 and details as follows:

WORM

Pitch (Distance from centre to centre of teeth.) = c
Lead (Advance in one revolution.) =
Hub Diameter = h
Bore = b
Angle of Thread = a
Pitch Diameter = d
Outside Diameter = o
Length = f
Projection of Hub = n
Key seat = k.s.
Material
Right or left-hand.

WORM GEAR

Number of teeth =
Pitch (circular) = C
Face = F
Bore = B
Hub Diameter = H
Pitch Diameter = D
Throat Diameter = O
Length through Hub = L
Projection from Centre = M
Key Seat = K.S.
Material
Right or left-hand.

Distance between Centres = A.

SPIRAL GEARS OR HELICAL GEARS

Spiral gears are shown in diagram 3, showing the position of the thrust bearings, direction of rotation and right and left-hand spirals for parallel shafts. The drivers are at the bottom and the driven gears at the top for the 4 left gears, and the drivers at the top for the 4 right gears.

Spiral gears for shafts at 90° are shown in diagram 4, showing the position of thrust bearings, direction of rotation and angle of teeth to show right or left-hand. The upper diagrams have drivers at the bottom and driven gears above. The bottom left and right-hand diagrams show the drivers beneath and the driven gears above.

These sketches are diagrammatic in form to illustrate the various applications of spiral or helical gear drives.

Exercises.

1. On a 9″x12″ sheet of drawing paper sketch the diagrams shown, and name drivers and followers.
2. On a piece of writing paper make out an order for a worm and worm gear.

CHAIN TRANSMISSION

A chain drive has the flexibility of a belt drive and the positive features of a gear drive. Three types of chain transmission are commonly used.

The Roller Chain, shown in Diagram 1.

The Block Chain, shown in Diagram 2.

The Silent Chain, shown in Diagram 3.

The selection of the type of chain to give the best results depends upon space available, constant or intermittent load, power to be transmitted and speed of the chain.

Block Chains are used for light loads and for speeds from 600 feet to 800 feet per minute.

Roller Chains are used for comparatively medium loads and for speeds from 800 feet to 1200 feet per minute.

Silent Chains are used for heavy loads and for speeds from 1200 feet to 1400 feet per minute.

Roller and high speed silent chains should have an even number of links in the chain to avoid using an offset connecting link. An odd number of teeth should be used in the pinion sprocket as this helps to distribute the wear.

Avoid vertical drives if possible, and have some adjustment provision for centre distance.

Do not use small sprockets unless the speed is slow and the load is light, as they cause noise and will unduly wear the chain.

Number of teeth for sprockets. Use at least 8 teeth for block chain, 12 teeth for roller chain, and 15 teeth for high speed silent chain. The greater the number of teeth that can be used, the better it will be for quiet running and long life. A slight sag on the chain is a desirable feature.

Wheel Types. These are shown in section in diagram 4. (A) shows how a silent chain is kept on the wheel teeth by the side links guiding the chain by overhanging the two sides of the wheel.

Two flanges are shown at (C) guiding the chain.

The most common method is the one shown at (B), with a groove cut in the wheel to receive the guide links which are fitted in the centre of the chain to give a positive guiding action.

Sprocket Types. These are shown in section with four different types in diagram 5. A sketch similar to one of these should be sent with an order.

Ordering information required.

1. Sketch the type of drive showing driver and follower positions.
2. Specify whether roller, block or silent chain.
3. Show direction of rotation.
4. Distance between shaft centres.
5. Horse-power to be transmitted.
6. Revolutions per minute.
7. Pitch of chain. (P) in sprocket sketch.
8. Width of chain.
9. Type of sprocket, A, B, C, or D, diagram 5.
10. Material.
11. Bore. (B).
12. Length of hub, (L).
13. Outside diameter of hub,(H).
14. Number of teeth.
15. Size of key seat, (K.S.).
16. Diameter of sprocket, (D).

Rolling joint silent chain. One of the many types of roller joints is shown in diagram 6 with a convex pintle rolling against a concave one. The chain is laced together with alternate staggered links.

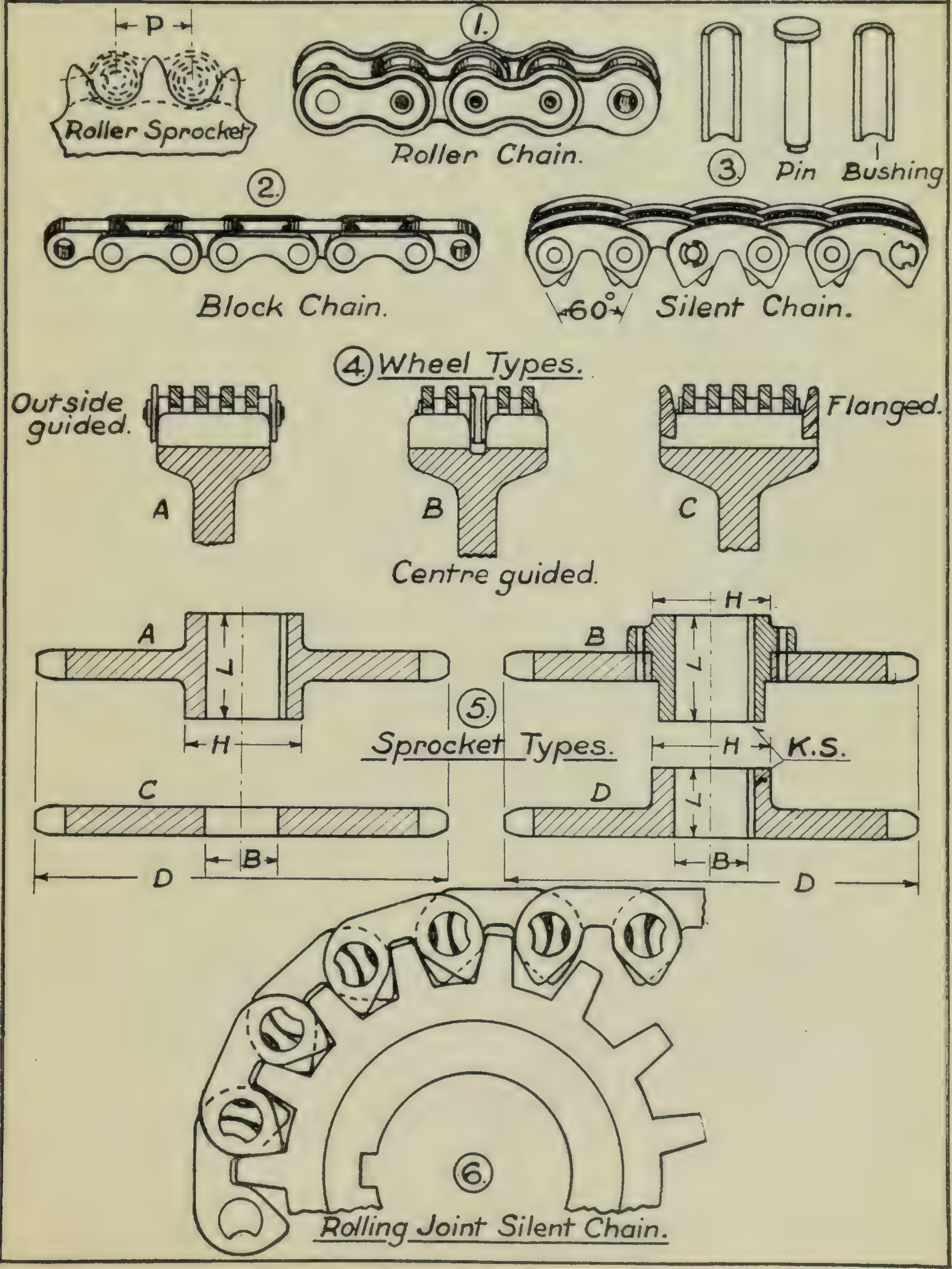
A pin-bushed joint is shown in the silent chain in diagram 3. The segmental liners or bushings extend across the width of the chain. The bushings are case-hardened and bear against the case-hardened pin which rotates freely to give uniform wear.

Lubrication and care of chain drives. If possible, the chain drive should be enclosed to prevent the wearing action of dust and grit. Provision should be made for lubricating the chain. If the chain becomes dirty it should be cleaned in gasoline or kerosene, and when dry it should be soaked in a heavy melted lubricant and then be treated with flaked graphite.

Exercise.

On a 9″ x 12″ piece of paper sketch the diagrams shown with the aid of your instruments.

CHAIN TRANSMISSION.



GRINDER DETAILS

The three diagram sheets which follow show the detail drawings of a typical shop grinder which is designed to carry two 2″ x 12″ x 1¼″ bore Abrasive Wheels.

The machine may be described as follows:—It has a heavy machine steel spindle with a right and left-hand square thread cut on the ends. The abrasive wheels are held between two collars at each end. The inside collars are a forced fit on the shaft, and the outside collars a sliding fit. The pressure between the flanges is exerted by square threaded right and left-hand nuts turning on the threaded spindle. The spindle is driven by a two step cone pulley which is positively keyed to the shaft. The spindle rotates in babbitted bearings with lubricating facilities provided. The rests are adjustable giving a variety of positions. Wheel guards are not shown, but would have to be provided before the grinder could be used with safety. The grinder frame could be fastened to a bench or bolted to a suitable cast iron pedestal.

The Frame is made of cast iron with a hollow inside as shown in section at EF. The upper faces are machined to receive the two caps which are made of cast iron and machined to fit the frame to give positive alignment to the bearings.

Dovetail slots are cast in the frame and caps to provide anchors for the babbitt.

The babbitt bearings are shown in section on AB and CD in the right-hand upper diagram 3. The longitudinal section at AB shows the babbitt on the inner sides of the frame designed to receive the end thrust of the spindle, exerted by the running faces of the two step pulley.

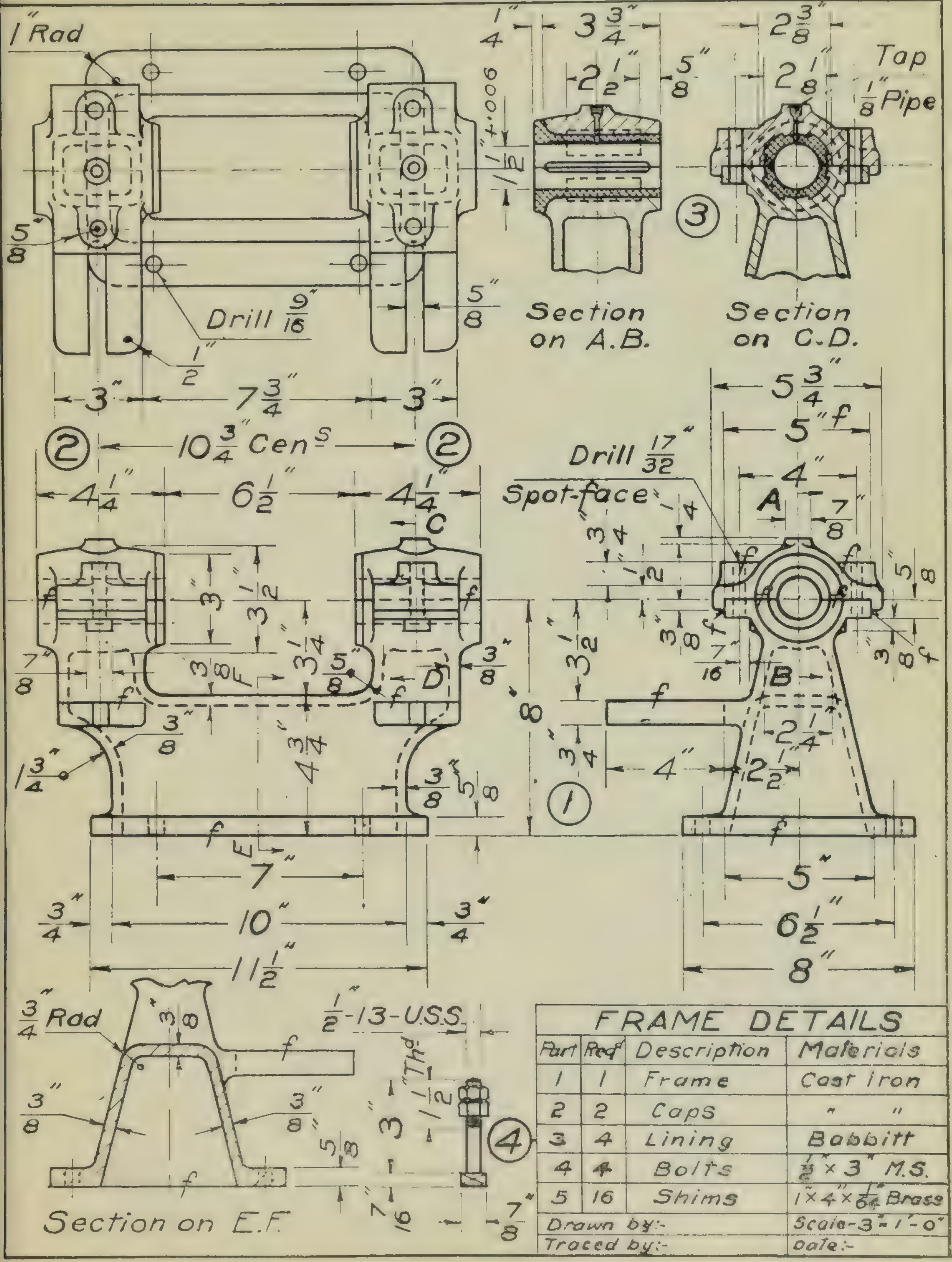
Lubrication of bearings is provided for by tapping the caps with a ⅛″ pipe tap into which may be fitted a suitable lubricating device. The lubricant is distributed by grooves cut in the babbitt from the hole where the lubricant enters the bearing. (See lesson on bearings, pages 116, 117, 118).

Bearing Assembly. This is secured with two ½″ square-headed bolts in each bearing. The square heads are prevented from turning by fitting to the flat provided on the under side of the frame.

Brass shims are fitted between the caps and the frame to provide for adjustment due to wear. The brass shims being soft would not injure the shaft if they came in contact with it. Holes are provided in the shims so that they may be fitted over the bolts which hold the bearing in place. (Look up lesson on Simple Horizontal Surface Contact Bearings for further instruction on bearing design, page 116).

Grinder rests. Brackets extend from the grinder frame with plain slots cast in them to receive the bolts which clamp the rests securely in any desired position.

GRINDER DETAILS



FRAME DETAILS

Part	Req^d	Description	Materials
1	1	Frame	Cast Iron
2	2	Caps	" "
3	4	Lining	Babbitt
4	4	Bolts	$\frac{1}{2}$" × 3" M.S.
5	16	Shims	1" × 4" × $\frac{1}{64}$" Brass
Drawn by:-			Scale-3"=1'-0"
Traced by:-			Date:-

The rest brackets (diagrams 4 and 5, page 174) are made right-hand and left-hand, and a tee slot is cast in each rest into which fits the tee-headed bolt which is used to clamp the rest bracket to the frame. The top of the rest in each case fits around the abrasive wheel to support metal when being ground on the periphery or the side of the wheel. The rests are provided with a vertical adjustment for height by moving up or down in the reamed hole provided in the rest bracket. A cap screw tightens the rest in position due to the cast slot allowing the bracket rest to clamp tightly around the vertical pin of the rest.

Spindle details. The spindle (diagram 4, page 173) is provided with a keyway to receive the key shown in diagram 7. The pulley (diagram 3) is fitted to the spindle with a press fit and the parallel key is held with a socketed set-screw in the pulley.

The spindle is .003″ oversize to make a forced fit in the inner flanges to give a positive drive to the flange and wheel. The outer flanges are fitted loosely, the spindle at these points being .003″ undersize.

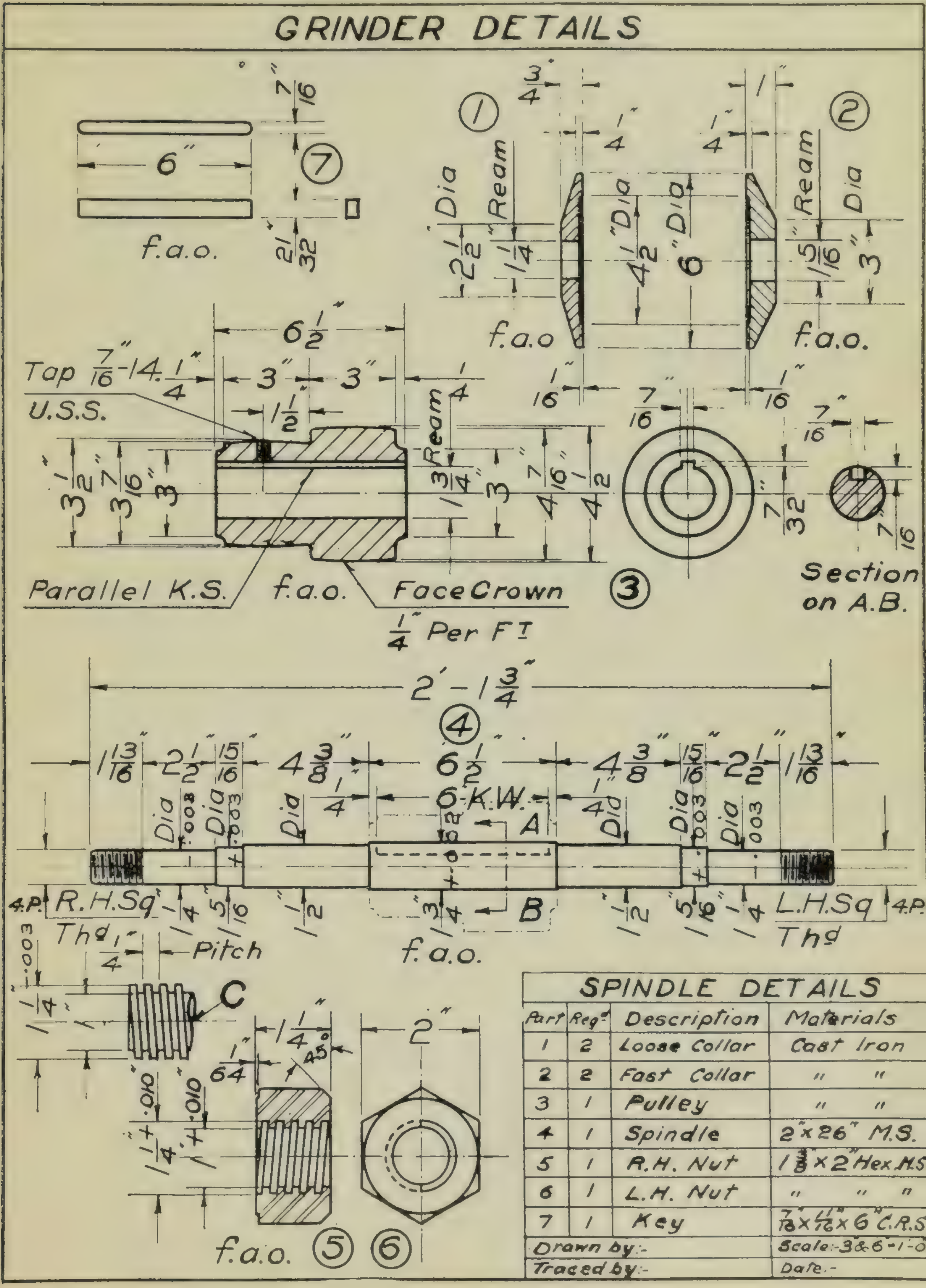
The spindle thread is shown enlarged at (C). It must be noted that a spindle may run in one direction so that the pressure on the wheels when transferred to the flanges and nuts would tend to loosen the nuts, or if run in the correct direction the pressure on wheels would automatically tighten both nuts.

Exercises.

1. On three separate pieces of drawing paper, size 9″ x 12″, draw the detail drawings as shown. Scale 3″ = 1′—0″.

2. On a 12″ x 18″ piece of drawing paper, draw the grinder assembled, plan, elevation and end elevation. Scale 4″ = 1′—0″. Put in reference numbers and omit dimensions.

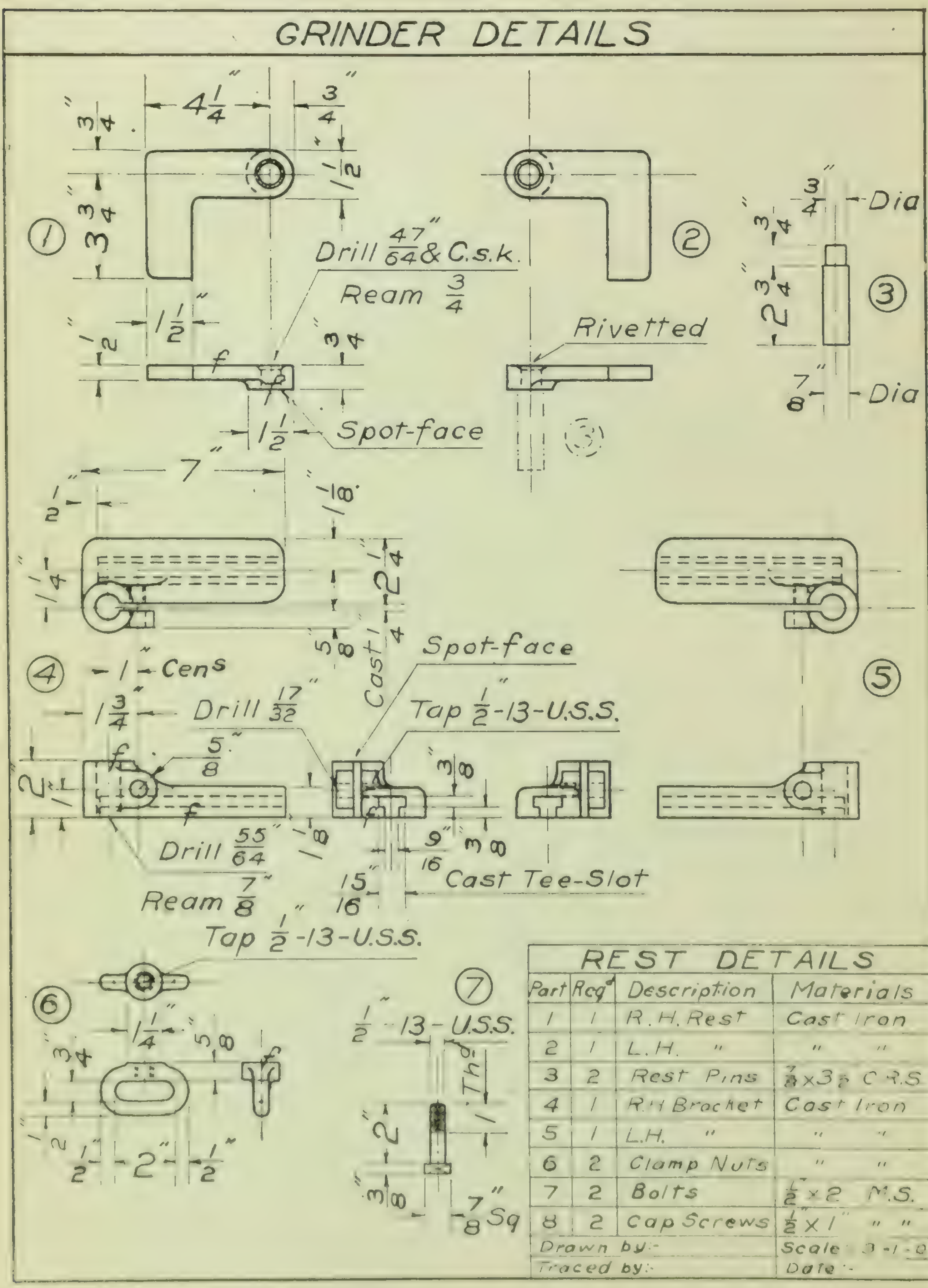
Note. Arrange the threads of the spindle so that they function correctly when viewed from the operator's position as shown in the front elevation.



SPINDLE DETAILS

Part	Reqᵈ	Description	Materials
1	2	Loose Collar	Cast Iron
2	2	Fast Collar	" "
3	1	Pulley	" "
4	1	Spindle	2" x 26" M.S.
5	1	R.H. Nut	1 3/8" x 2" Hex M.S
6	1	L.H. Nut	" " "
7	1	Key	7/16" x 11/16" x 6" C.R.S
Drawn by:-			Scale:-3&6-1-0
Traced by:-			Date.-

GRINDER DETAILS



REST DETAILS

Part	Req^d	Description	Materials
1	1	R.H. Rest	Cast Iron
2	1	L.H. "	" "
3	2	Rest Pins	$\frac{7}{8}$ x 3$\frac{1}{2}$ C.R.S
4	1	R.H. Bracket	Cast Iron
5	1	L.H. "	" "
6	2	Clamp Nuts	" "
7	2	Bolts	$\frac{1}{2}$" x 2 M.S.
8	2	Cap Screws	$\frac{1}{2}$" x 1" " "
Drawn by:-			Scale: 3"-1'-0"
Traced by:-			Date:-

QUESTIONS:

1. Explain the following terms:—
    - (a) Pitch diameter.
    - (b) Circular pitch.
    - (c) Module and addendum.
    - (d) Diametral pitch.
2. If the pitch circles of a 6 (D.P.) 28T gear and 14T pinion were 4.667″ and 2.333″ respectively, what would be their outside diameters and the centre distance?
3. Which of the following give the ratio of a gear and pinion?
    - (a) Pitch circle diameters.
    - (b) Outside diameters.
    - (c) Number of teeth.
4. What is the circular and diametral pitch of a gear with 20T and 5″ pitch diameter? What is the outside diameter of this gear?
5. What is the base circle of a standard gear? How is it found?
6. Illustrate by means of a diagram the use of the following terms:—
    - (a) Addendum.
    - (b) Dedendum.
    - (c) Clearance.
    - (d) Whole depth of tooth.
    - (e) Working depth.
7. What is the addendum and working depth of a 4 D.P. gear?
8. What is the "circular pitch", "thickness of tooth" and "clearance". of a 10 P gear with 22 teeth?
9. Sketch 2 gear teeth showing the fillet radius and how the amount of it is found.
10. What is the pitch diameter and outside diameter of a 1¾″ circular pitch gear with 20 teeth?
11. Show by means of 2 sketches the features and differences between a 14½° pressure angle gear tooth and a 20° pressure angle stub tooth. What is each type of gear used for?
12. What is the cycloidal system of gear teeth?
13. What is meant by a 4/5 D.P. gear tooth? Illustrate with a sketch.
14. Make a sketch of a rack tooth showing the pressure angle and other angles of the tooth for a 14½° pressure angle.
15. Sketch in section the approximate shapes of two milling cutters for cutting a 14½° rack tooth and a 12-tooth pinion.
16. What is the circular pitch of a rack to mesh with a 4 D.P. pinion?
17. If you were given a pinion to make a gear to mesh with it, what measurements and particulars would you obtain from the pinion to enable you to make the gear?
18. List the information that would be necessary to enable you to turn and mill a gear.
19. What materials are used in gear manufacture? State the reasons for the use of each material.
20. Explain with sketches the following terms used in reference to Bevel Gears:—
    - (a) Gear pitch cones.
    - (b) Back cone radius.
    - (c) Backing.
    - (d) Pitch.

21. What is meant by the following?—
    (a) Bevel gear.
    (b) Mitre gear.
    (c) Crown gear.
22. Explain why the term "helical gear" is correct and "spiral gear" incorrect.
23. State in how many ways Helical Gears may be used to connect shafts.
24. Show by means of a sketch how you can distinguish a right-hand from a left-hand Helical Gear.
25. Show by means of a sketch what is meant by the "lead" of a Helical Gear.
26. What advantages do Helical Gears have over Spur Gears?
27. Sketch and state the features of a Herringbone Gear.
28. What is the drive ratio of a worm and worm gear, as follows:—
    (a) Single-threaded worm.
    (b) Double-threaded worm.
    (c) Triple-threaded worm.
    When meshed with a 36 tooth worm gear in each case?
29. State the features of worm gearing.
30. Make two sketches showing the positions of the thrust bearing for:—
    (a) Helical gears connecting parallel shafts,
    (b) Helical gears connecting shafts at right angles.
31. Compare the following types of drive:—
    (a) Spur gear drive.
    (b) Chain transmission drive.
32. Sketch a few links of:—
    (a) Roller chain.
    (b) Block chain.
    (c) Silent chain, with details of some form of rolling joint.
33. Sketch in section a centre guided sprocket wheel showing chain in position.
34. Sketch a few gear teeth showing the proportions used for cast gears.
35. On a 9″ x 12″ piece of paper, lay out 3 teeth, 2″ circular pitch for a cast gear of 20 teeth by use of Grant's Odontograph.
36. Draw in section the reduction unit shown on page 114, and figure out its drive ratio.
37. What is meant by the following terms—
    (a) Helix angle of a thread.
    (b) Drunken thread.
    (c) Tolerance.
    (d) Quadruple thread.
    (e) Pitch diameter of a screw.

BAR STEEL — WEIGHT PER LINEAL FOOT

SQUARE		ROUND		OCTAGON	
Size	Pounds	Size	Pounds	Size	Pounds
⅛	.05	⅛	.04	⅛	.04
3/16	.12	3/16	.09	3/16	.10
¼	.21	¼	.17	¼	.18
5/16	.33	5/16	.26	5/16	.28
⅜	.48	⅜	.38	⅜	.40
7/16	.65	7/16	.51	7/16	.54
½	.85	½	.67	½	.70
9/16	1.08	9/16	.85	9/16	.89
⅝	1.33	⅝	1.04	⅝	1.10
11/16	1.61	11/16	1.27	11/16	1.33
¾	1.92	¾	1.50	¾	1.58
13/16	2.24	13/16	1.76	13/16	1.83
⅞	2.60	⅞	2.04	⅞	2.16
15/16	3.06	15/16	2.35	15/16	2.48
1	3.40	1	2.67	1	2.82
1⅛	4.30	1⅛	3.38	1⅛	3.56
1¼	5.31	1¼	4.17	1¼	4.40
1⅜	6.43	1⅜	5.05	1⅜	5.32
1½	7.65	1½	6.01	1½	6.34
1⅝	8.98	1⅝	7.05	1⅝	7.32
1¾	10.40	1¾	8.18	1¾	8.64
1⅞	11.90	1⅞	9.38	1⅞	9.92
2	13.60	2	10.71	2	11.28
2⅛	15.40	2⅛	12.05	2⅛	12.71
2¼	17.20	2¼	13.60	2¼	14.24
2⅜	19.20	2⅜	15.10	2⅜	15.88
2½	21.20	2½	16.68	2½	17.65

FLAT BAR STEEL—WEIGHT PER LINEAL FOOT

	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2
1/8	.213	.266	.320	.372	.426	.479	.530	.585	.640	.745	.850	.955	1.07
3/16	.319	.399	.480	.558	.639	.718	.790	.878	.960	1.12	1.28	1.43	1.60
1/4	.425	.533	.640	.743	.852	.958	1.06	1.17	1.28	1.49	1.70	1.91	2.13
5/16	.531	.665	.800	.929	1.06	1.20	1.33	1.46	1.60	1.86	2.13	2.39	2.66
3/8	.638	.798	.960	1.12	1.28	1.33	1.59	1.75	1.91	2.23	2.55	2.87	3.20
7/16	.744	.931	1.12	1.30	1.49	1.67	1.86	2.05	2.33	2.60	2.98	3.35	3.72
1/2	....	1.07	1.28	1.49	1.70	1.91	2.13	2.34	2.55	2.98	3.40	3.83	4.26
9/16	....	1.20	1.44	1.67	1.91	2.15	2.39	2.63	2.87	3.35	3.83	4.30	4.78
5/8	....	....	1.60	1.86	2.12	2.39	2.66	2.92	3.19	3.72	4.26	4.79	5.32
11/16	....	....	1.76	2.04	2.34	2.63	2.92	3.22	3.51	4.09	4.68	5.26	5.84
3/4	....	....	....	2.23	2.55	2.86	3.19	3.50	3.83	4.46	5.10	5.74	6.40
13/16	....	....	....	2.41	2.76	3.11	3.45	3.80	4.14	4.83	5.53	6.22	6.91
7/8	....	....	....	....	2.98	3.34	3.72	4.09	4.46	5.21	5.96	6.70	7.46
15/16	....	....	....	....	3.19	3.59	3.98	4.38	4.78	5.58	6.38	7.17	7.97
1	....	....	....	....	....	3.82	4.25	4.68	5.10	5.96	6.80	7.66	8.52
1 1/8	....	....	....	....	....	....	4.78	5.27	5.74	6.71	7.65	8.61	9.59
1 1/4	....	....	....	....	....	....	....	5.85	6.38	7.45	8.50	9.57	10.65
1 1/2	....	....	....	....	....	....	....	7.02	7.67	8.94	10.21	11.49	12.78

SCREW THREAD TERMS

Allowance—The difference in dimensions between the minimum hole and the maximum screw.

Angle of Thread—The angle of thread is the angle included between the sides of the thread, measured in an axial plane.

Axis of Screw—The longitudinal central line through the screw from which all corresponding parts are equally distant.

Base of Thread—The bottom section of a thread; the greatest section between the two adjacent roots.

Basic—The theoretical or nominal standard size from which all variations are made.

Crest—The top surface joining the two sides of a thread.

Crest Clearance—Defined on a screw form as the space between the crest of a thread and the root of its component.

Depth of Engagement—The depth of a thread in contact, of two mating parts—measured radially.

Depth of Thread—The depth of thread, in profile, is the distance between the top and the base of thread measured normal to the axis.

Flute—That portion cut away between the lands. (Taps, reamers, etc.)

Helix Angle—The angle made by the helix of a thread at the pitch diameter with a plane perpendicular to the axis.

Land—That portion of a thread not cut away by the flutes. (Taps, reamers, etc.)

Lead—The distance a screw thread advances axially in one turn. On a single screw thread the lead and pitch are identical; on a double thread screw the lead is twice the pitch; on a triple thread screw the lead is three times the pitch, etc.

Length of Engagement—The length of contact between two mating parts measured axially.

Limits—The extreme dimensions which are prescribed to provide variations in fit and workmanship.

Major Diameter—Commonly known as outside diameter. On a straight screw thread the major diameter is the largest diameter of the thread on the screw or nut. The term "major diameter" replaces the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut.

Minor Diameter—Commonly known as core or root diameter. On a straight screw thread the minor diameter is the smallest diameter of the thread on the screw or nut. The term "minor diameter" replaces the term "core diameter" and "root diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut.

SCREW THREAD TERMS (continued)

Number of Threads—The number of threads in 1 inch of length.

Pitch—The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. The pitch equals 1 divided by the number of threads per inch.

Pitch Diameter—On a straight screw thread the pitch diameter is the diameter of an imaginary cylinder which would pass through the threads at such points as to make the width of the thread and the width of the spaces between the threads at these points equal.

Relief—The amount of metal removed from behind the cutting edge to reduce friction. An indefinite term when applied to a tap or die. To be clear it should be specified whether relief on the chamfer or relief in the angle of the thread is meant.

Root—The bottom surface joining the sides of two adjacent threads.

Screw Thread—A screw thread is a ridge of some desired profile generated in the form of a helix on the inside or outside of a cylinder or cone.

Side of Thread—The surface of the thread which connects the crest with the root.

Thread, Single—A thread in which the lead is equal to the pitch.

Thread, Double—A thread in which the lead is equal to two times the pitch.

Thread, Triple—A thread in which the lead is equal to three times the pitch.

Thread, Quadruple—A thread in which the lead is equal to four times the pitch.

> **Note**—In ordering tools with multiple threads, be sure to specify both pitch and lead as 12 Pitch, 6 lead.

Thread, Buttress—One with one side at right angles and the other side at 45° to the screw axis. The right angular side is always used as the thrust side. This thread has a symmetrical form and a depth of .75 x pitch.

Thread, Drunken—A thread in which the advance of the helix is irregular.

Thread, Ratchet—Same form as Buttress Thread, but understood to be somewhat sharper at crest and root.

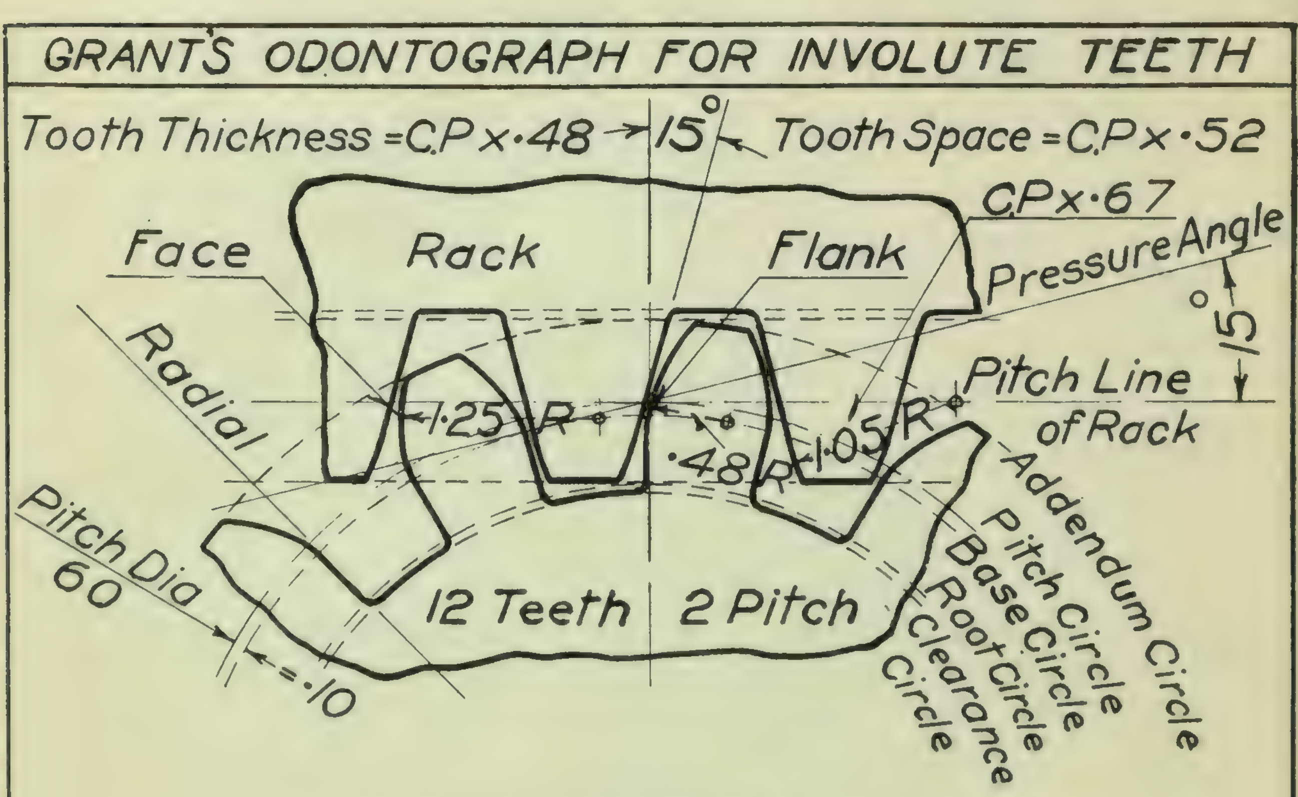
Thread, V—A form of thread having 60° angle and sharp top and bottom. Impossible in practice and always more or less modified to suit individual conditions.

Tolerance—The difference between the limits or maximum and minimum dimensions of a given part. A tolerance may be expressed as plus or minus, or both. A total tolerance is the sum of a plus and minus tolerance.

WEIGHT AND SPECIFIC GRAVITY OF METALS

	Specific Gravity Range According to Several Authorities	Specific Gravity Approximate mean Value Used in Calculation of Weight	Weight per Cubic Foot, Pounds	Weight per Cubic Inch, Pounds
Aluminum	2.56 to 2.71	2.67	166.5	.0963
Antimony	6.66 to 6.86	6.76	421.6	.2439
Bismuth	9.74 to 9.90	9.82	612.4	.3544
Brass, copper and zinc				
80 20	7.8 to 8.6	8.60	536.3	.3103
70 30		8.40	523.8	.3031
60 40		8.36	521.3	.3017
50 50		8.20	511.4	.2959
Bronze copper 95 to 80 tin 5 to 20	8.52 to 8.96	8.853	552.0	.3195
Cadmium	8.6 to 8.7	8.65	539.0	.3121
Calcium	1.58			
Chromium	5.0			
Cobalt	8.5 to 8.6			
Gold, pure	19.245 to 19.361	19.258	1200.9	.6949
Copper	8.69 to 8.92	8.853	552.0	.3195
Iridium	22.38 to 23.0		1396.0	.8076
Iron, cast	6.85 to 7.48	7.218	450.0	.2604
Iron, wrought	7.4 to 7.9	7.70	480.0	.2779
Lead	11.07 to 11.44	11.38	709.7	.4106
Manganese	7.0 to 8.0	8.00	499.0	.2887
Magnesium	1.69 to 1.75	1.75	109.0	.0641
Mercury 32°	13.60 to 13.62	13.62	849.3	.4915
60°	13.58	13.58	846.8	.4900
212°	13.37 to 13.38	13.38	834.4	.4828
Nickel	8.279 to 8.93	8.8	548.7	.3175
Platinum	20.33 to 22.07	21.5	1347.0	.7758
Potassium	0.865			
Silver	10.474 to 10.511	10.505	655.1	.3791
Sodium	0.97			
Steel	7.69* to 7.932†	7.854	489.6	.2834
Tin	7.291 to 7.409	7.350	458.3	.2662
Titanium	5.3			
Tungsten	17.0 to 17.6			
Zinc	6.86 to 7.20	7.00	436.5	.2526

*Hard and burned. †Very pure and soft. The specific gravity decreases as the carbon is increased. In the first column of figures, the lowest are usually those of cast metals, which are more or less porous; the highest are of metals finely rolled or drawn into wire.



GRANT'S ODONTOGRAPH FOR CAST GEARS

Table for Involute Teeth

Addendum=0.3183×Circular Pitch (C.P.) Clearance=Addendum÷8.

No. of teeth in the gear.	Radii for one Diametral Pitch, for any other Pitch divide values given by that Pitch.		Radii for one inch Circular Pitch; for any other Pitch multiply values given by that Pitch.		No. of teeth in the gear.	Radii for one Diametral Pitch, for any other Pitch divide values given by that Pitch.		Radii for one inch Circular Pitch; for any other Pitch multiply values given by that Pitch.	
	Face Radius	Flank Radius	Face Radius	Flank Radius		Face Radius	Flank Radius	Face Radius	Flank Radius
10	2.28	0.69	0.73	0.22	28	3.92	2.59	1.25	0.82
11	2.40	0.83	0.76	0.27	29	3.99	2.67	1.27	0.85
12	2.51	0.96	0.80	0.31	30	4.06	2.76	1.29	0.88
13	2.62	1.09	0.83	0.34	31	4.13	2.85	1.31	0.91
14	2.72	1.22	0.87	0.39	32	4.20	2.93	1.34	0.93
15	2.82	1.34	0.90	0.43	33	4.27	3.01	1.36	0.96
16	2.92	1.46	0.93	0.47	34	4.33	3.09	1.38	0.99
17	3.02	1.58	0.96	0.50	35	4.39	3.16	1.39	1.01
18	3.12	1.69	0.99	0.54	36	4.45	3.23	1.41	1.03
19	3.22	1.79	1.03	0.57	37–40	4.20		1.34	
20	3.32	1.89	1.06	0.60	41–45	4.63		1.48	
21	3.41	1.98	1.09	0.63	46–51	5.06		1.61	
22	3.49	2.06	1.11	0.66	52–60	5.74		1.83	
23	3.57	2.15	1.13	0.69	61–70	6.52		2.07	
24	3.64	2.24	1.16	0.71	71–90	7.72		2.46	
25	3.71	2.33	1.18	0.74	91–120	9.78		3.11	
26	3.78	2.42	1.20	0.77	121–180	13.38		4.26	
27	3.85	2.50	1.23	0.80	181–360	21.62		6.88	

DIAMETRAL PITCH TOOTH PARTS

Relation between Diametral Pitch and Circular Pitch, with corresponding Tooth Dimensions.

Diametral Pitch	Circular Pitch	Thickness of Tooth at Pitch Line	Whole Depth	Dedendum	Addendum
1/2	6.2832″	3.1416″	4.3142″	2.3142″	2.0000″
3/4	4.1888	2.0944	2.8761	1.5428	1.3333
1	3.1416	1.5708	2.1571	1.1571	1.0000
1-1/4	2.5133	1.2566	1.7257	0.9257	0.8000
1-1/2	2.0944	1.0472	1.4381	0.7714	0.6666
1-3/4	1.7952	0.8976	1.2326	0.6612	0.5714
2	1.5708	0.7854	1.0785	0.5785	0.5000
2-1/4	1.3963	0.6981	0.9587	0.5143	0.4444
2-1/2	1.2566	0.6283	0.8628	0.4628	0.4000
2-3/4	1.1424	0.5712	0.7844	0.4208	0.3636
3	1.0472	0.5236	0.7190	0.3857	0.3333
3-1/2	0.8976	0.4488	0.6163	0.3306	0.2857
4	0.7854	0.3927	0.5393	0.2893	0.2500
5	0.6283	0.3142	0.4314	0.2314	0.2000
6	0.5236	0.2618	0.3595	0.1928	0.1666
7	0.4488	0.2244	0.3081	0.1653	0.1429
8	0.3927	0.1963	0.2696	0.1446	0.1250
9	0.3491	0.1745	0.2397	0.1286	0.1111
10	0.3142	0.1571	0.2157	0.1157	0.1000
11	0.2856	0.1428	0.1961	0.1052	0.0909
12	0.2618	0.1309	0.1798	0.0964	0.0833
13	0.2417	0.1208	0.1659	0.0890	0.0769
14	0.2244	0.1122	0.1541	0.0826	0.0714
15	0.2094	0.1047	0.1438	0.0771	0.0666
16	0.1963	0.0982	0.1348	0.0723	0.0625
17	0.1848	0.0924	0.1269	0.0681	0.0588
18	0.1745	0.0873	0.1198	0.0643	0.0555
19	0.1653	0.0827	0.1135	0.0609	0.0526
20	0.1571	0.0785	0.1079	0.0579	0.0500
22	0.1428	0.0714	0.0980	0.0526	0.0455
24	0.1309	0.0654	0.0898	0.0482	0.0417
26	0.1208	0.0604	0.0829	0.0445	0.0385
28	0.1122	0.0561	0.0770	0.0413	0.0357
30	0.1047	0.0524	0.0719	0.0386	0.0333
32	0.0982	0.0491	0.0674	0.0362	0.0312
34	0.0924	0.0462	0.0634	0.0340	0.0294
36	0.0873	0.0436	0.0599	0.0321	0.0278
38	0.0827	0.0413	0.0568	0.0304	0.0263
40	0.0785	0.0393	0.0539	0.0289	0.0250
42	0.0748	0.0374	0.0514	0.0275	0.0238
44	0.0714	0.0357	0.0490	0.0263	0.0227
46	0.0683	0.0341	0.0469	0.0252	0.0217
48	0.0654	0.0327	0.0449	0.0241	0.0208
50	0.0628	0.0314	0.0431	0.0231	0.0200
56	0.0561	0.0280	0.0385	0.0207	0.0178
60	0.0524	0.0262	0.0360	0.0193	0.0166

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